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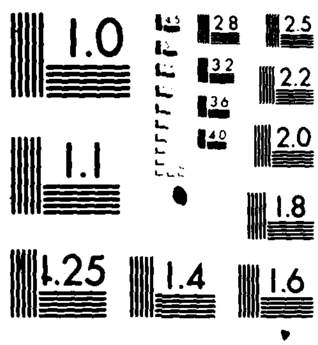

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PSR Report 1027

USERS' MANUAL FOR SNAP/D: SEISMIC NETWORK ASSESSMENT PROGRAM FOR DETECTION

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September 1980

Final Report
Contract AC90C114

Sponsored by
U. S. Arms Control and Disarmament Agency
Washington, D.C. 20451

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PREFACE

Verification of a comprehensive test ban treaty involves certain technical issues. This report, sponsored by the U.S. Arms Control and Disarmament Agency, is part of a continuing research program on such issues. It presents the analysis and code documentation for SNAP/D, a computer model for assessing the ability of a network to detect and locate seismic events. The module in SNAP/D that calculates the uncertainty in network location estimates was developed by Systems, Science and Software under sponsorship of the Defense Advanced Research Projects Agency.

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ACKNOWLEDGMENTS

The authors are indebted to Eugene Herrin of Southern Methodist University, Jack F. Evernden of the U.S. Geological Survey, and Ralph W. Alewine of the Defense Advanced Research Projects Agency (DARPA) for their help in resolving certain seismological issues. John M. Savino and William L. Rodi of Systems, Science and Software also made valuable suggestions during development of the DARPA-sponsored LOCATE module. Robert I. Berg of the U.S. Arms Control and Disarmament Agency both oversaw the research and contributed to the design of the interactive routines.

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I. INTRODUCTION AND SUMMARY

This report is a user's manual for SNAP/D (Seismic Network Assessment Program for Detection), a computer model designed by ~~Pacific-Sierra Research Corporation~~ (PSR) for assessing the ability of a network to detect and locate seismic events (i.e., earthquakes or explosions). Part I presents the analytical structure of the model, whereas Part II documents the computer code.

PSR plans to develop another model, SNAP/I, for assessing the ability of a seismic network to *identify* earthquakes and explosions [Ciervo, 1978]. SNAP/D will be used as a starting point for SNAP/I, inasmuch as a seismic event must be detected before it can be identified. Therefore, SNAP/D includes many features that will be used by SNAP/I to distinguish earthquakes from explosions. For example, the user can specify, for any SNAP/D run, either an explosion, a shallow earthquake, or a deep earthquake—each of which propagates waves at relatively different average amplitudes.

In addition to its eventual role in SNAP/I, SNAP/D is expected to be of immediate use to analysts concerned with test ban treaty verification. It is intended to replace NETWORTH [Wirth, 1977], the computer model that has gained wide acceptance in the verification community for assessing network performance. SNAP/D has a much broader scope than NETWORTH. For example, SNAP/D

- "Propagates" (models the propagation of) up to 10 seismic waves in a single run.
- Calculates wave attenuation and travel time as functions of focal depth, regional media characteristics, and event type.
- Allows user specification of multiwave network detection criteria.
- Accommodates advanced seismological techniques for determining the uncertainty in estimates of focal depth and epicenter location, such as

  - Master-event calibration of P travel times,
  - S-P origin-time fix,
  - pP depth estimates with step-out,
  - Lg back azimuth estimates.
- Calculates the relative importance of individual waves and stations to hypocenter estimates.
- Easily incorporates new waves or techniques because of its modular design.
- Allows the user to initiate runs in either an interactive or a batch mode.

The seismic waves (or phases) propagated in the model include P, Pn, Pg, Lg, Sn, S, pP, and Rayleigh, with provision for propagating four additional phases. The existence and attenuation of each phase with epicentral distance is keyed to event type (earthquake or explosion), focal depth, and event size (generally given in m_b units). In addition, regional media characteristics along the propagation path are used to compute the expected amplitude of each phase observed at a given station.

At the start of each run, the user selects either an explosion at zero depth, a shallow earthquake at 15 km depth, or a deep earthquake at 100 km depth. The selected event is assumed to occur over one or several grids of hypothetical epicenters. In its most common operating mode, SNAP/D computes the minimum magnitude in m_b units, at each epicenter, that provides a given probability that the selected network of stations will meet the selected multiwave detection criteria. For example, at a given epicenter, SNAP/D could compute, with 0.90 probability, the smallest explosion (in m_b units) that would result in at least a four-station P-wave observation or a two-station P- and Lg-wave observation.

SNAP/D can also calculate, for each hypothetical epicenter, the epicentral error ellipse and depth confidence interval at any user-specified level. The generalized inversion technique used to compute

those statistical parameters incorporates multiwave arrivals at all stations as well as specialized propagation-path calibration procedures specified by the user. The procedures include master-event calibration of P-wave travel times, pP depth estimates with step-out, and S-P origin-time fix. Back azimuth estimates from Lg-wave observations are also included in the error calculations. The relative "importance" of individual waves and stations to the precision of hypocenter estimates at any epicenter, or set of epicenters, may also be computed.

PART I

ANALYTICAL MODEL

II. MACROSTRUCTURE

This section specifies the waves propagated in SNAP/D, describes the SNAP/D modules, and presents a flowchart of the data passed between modules. The modular design of SNAP/D has proved valuable in conceptualizing and describing model operations. However, some modules contain several subroutines, and some subroutines contain more than one module. Part I presents SNAP/D from a modular point of view, whereas Part II describes the operation of the subroutines.

SEISMIC WAVES

Table 1 lists the waves propagated in SNAP/D along with their primary functions (detection, location, or identification), regional propagation path corrections, and seismic source. The P and Pn as well as the S and Sn phases have been combined into one wave for shallow events (explosion or shallow earthquake), because of nearly nonoverlapping ranges and similar functions. The reflected phase pP represents both pP and sP in SNAP/D, since both serve a similar function in depth estimation but are rarely observed by the same station for a given event. Furthermore, because sP is more sensitive than pP to variations in depth, we can conservatively assess the role of the reflected phases in depth estimation by using the pP travel-time table to represent both pP and sP travel times.

Although any wave listed in Table 1 may be included in the network detection criteria, detection is listed as a primary function only for waves that have either been traditionally used for network detection or are proposed for such use. Since network detection criteria have been based on the ability of the network to *locate* an event, any wave in SNAP/D that is listed for detection is also listed for location (i.e., used to calculate the precision of epicenter location and focal depth estimates). Further, since we plan to incorporate SNAP/D into an identification model (SNAP/I), we have made the

Table 1

WAVES PROPAGATED IN SNAP/D

Wave	Functions[a]	Regional Media Corrections	Source[b]
P (and Pn)	Detection Location (master event, S-P) Identification (M_s:m_b, m_{Lg}:m_b, first motion)	Attenuation	X $Q_{\bar{D}}$ Q_D (no Pn; new attenuation and travel-time tables)
Pg	Detection Location Identification	Attenuation	X $Q_{\bar{D}}$
Lg	Detection Location (back azimuth) Identification (m_{Lg}:m_b)	Attenuation (squelched by ocean and mountains)	X $Q_{\bar{D}}$ (larger amplitude)
S (and Sn)	Location (S-P)	Attenuation	X $Q_{\bar{D}}$ (larger amplitude) Q_D (no Sn; new attenuation table)
pP	Location (step-out)	None	Q_D
Rayleigh	Identification (M_s:m_b)	None	X $Q_{\bar{D}}$ (larger amplitude) Q_D (smaller amplitude)
Four additional phases	Identification	Attenuation	X $Q_{\bar{D}}$ Q_D

[a]The identification functions are relevant to the planned SNAP/I model.

[b]X, explosion (0 km); $Q_{\bar{D}}$, shallow earthquake (15 km); Q_D, deep earthquake (100 km).

provision for propagating waves that will be used for identifying seismic events. The Rayleigh wave used in the $M_s:m_b$ discriminant is one such wave, but SNAP/D can also propagate four additional phases for use in seismic discrimination.

In addition to the traditional least squares "triangularization" process based on arrival times, Table 1 indicates the advanced location techniques modeled in SNAP/D. Thus, for a user-specified set of stations calibrated with respect to any epicenter, SNAP/D accounts for both master-event (i.e., large earthquake) calibration of P arrivals and v_P/v_S path calibration for use in determining origin time from the difference between S and P arrivals. The sets of calibrated stations for any epicenter are specified separately for each type of calibration (master-event or S-P), and each source depth (shallow or deep). The Lg phase provides back-azimuth rather than arrival-time information for calculating the precision of hypocenter estimates. SNAP/D also models the "step-out" procedure for use with the reflected phase pP for depth estimation.

At the start of each run, the user can choose from three event-type/focal-depth combinations: (1) an explosion (X) at zero depth; (2) a shallow earthquake ($Q_{\bar{D}}$) at 15 km depth; or (3) a deep earthquake (Q_D) at 100 km depth. Table 1 summarizes the general effect of that choice on the waves propagated in the model. As shown in the table, SNAP/D usually performs the amplitude corrections for different events by adding factors to magnitudes computed from standard attenuation tables. However, a new travel-time table is required for P-wave propagation from a deep earthquake.

In general, the probability that a given station will observe a given wave from any epicenter is computed from the expected amplitude and standard deviation of the wave and associated noise at that station. The expected amplitude of the wave is found from a standard attenuation table (or tables) corrected for event size (in m_b units), event type, and regional media characteristics along the propagation path. However, propagation path corrections are made only when the

source is shallow (X or $Q_{\bar{D}}$) and the distance from epicenter to station is less than 20 deg. Propagation path corrections begin by computing the relative portion of the path that lies in tectonic or intermediate (as opposed to stable) rock from a user-specified regional media grid. That computation is then used to obtain the expected wave amplitude for a given epicentral distance by interpolating between stable and tectonic attenuation tables. Similarly, SNAP/D accounts for Lg phase attenuation by large bodies of water and mountain ranges by means of a user-specified "Lg squelch" grid.

INFORMATION ROUTING

Figure 1 shows the flowchart of SNAP/D. The control inputs serve two major purposes: first, they define the nature of the run (detection or location, explosion or earthquake, focal depth, etc.); second, they preset all other inputs and modules so that unnecessary functions are not performed during a model run. Detection inputs define the network detection criteria and such associated parameters as the probability threshold for output magnitude contours. Epicenter inputs establish the grid of test epicenters. Regional inputs provide the grid of regional corrections for local wave propagation. Station inputs include station location, reliability, and noise statistics. The calibration and importance inputs, respectively, specify the epicenter/station pairs for travel-time calibration and importance-matrix calculations. The wave inputs primarily consist of amplitude and travel-time tables and associated statistics. A detailed description of all inputs is presented in the next section.

The calculation modules shown in Fig. 1 have been chosen for easy conceptualization of SNAP/D. Each module may contain several subroutines of the computer program or vice versa (as discussed in Part II of this report). Each module function is summarized below and detailed in Sec. IV.

- TRANS--Translates the multiwave detection criteria into two types of canonical calculations, then uses the calculations

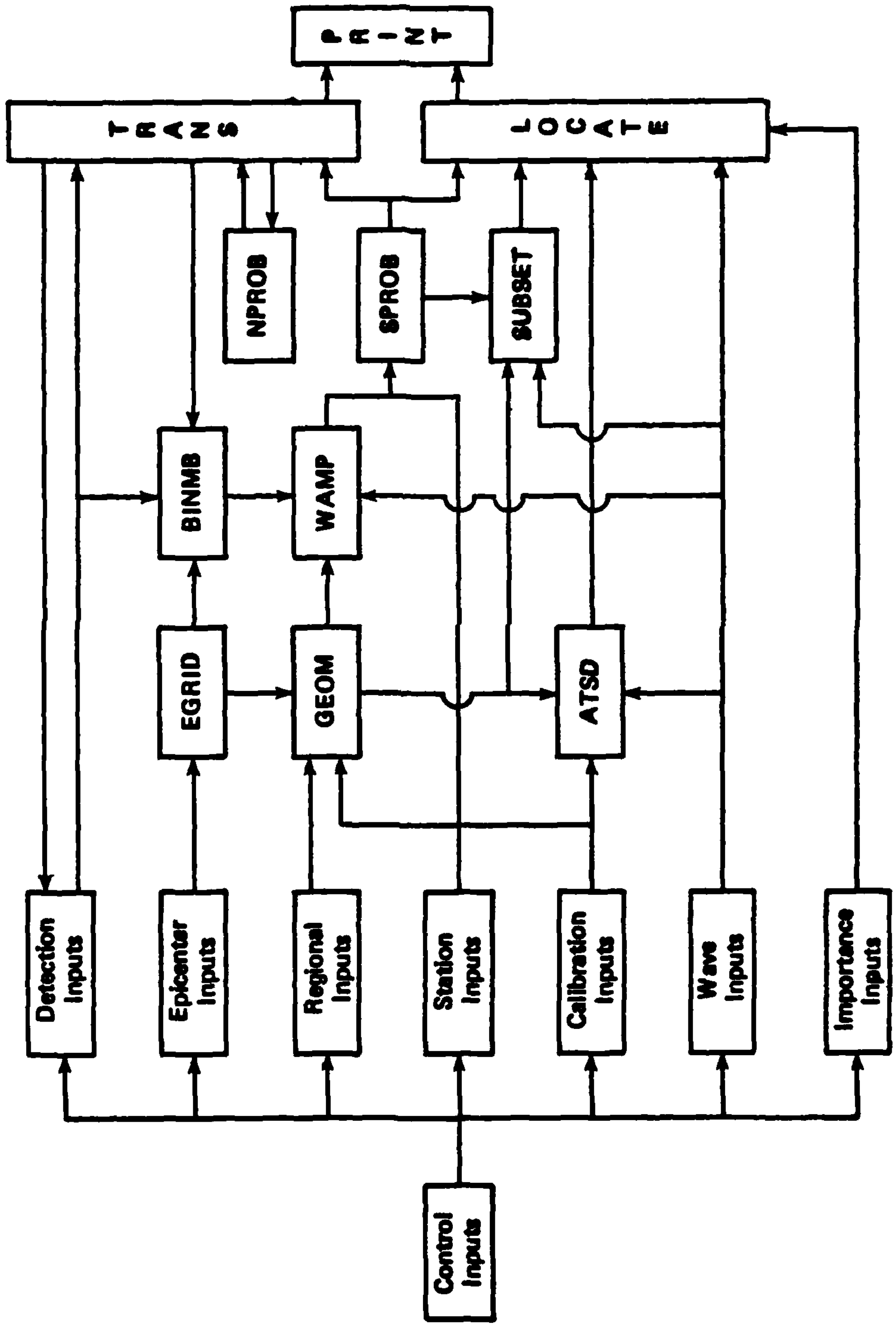

Fig. 1--Flowchart of SNAP/D

to compute the network detection probability. TRANS also initiates printing of an error message if the user enters inadmissible detection criteria. Network detection criteria are entered in a simple, intuitive format.

- NPROB--Performs the canonical probability calculations required by TRANS.
- EGRID--Uses the epicenter inputs to set up the grid of test epicenters, and increments the program from epicenter to epicenter,
- BINMB--Increments the program, through magnitude values, in a binary search for the magnitude that results in network detection at the user-entered probability threshold. BINMB performs these operations for each test epicenter.
- GEOM--Calculates the great-circle geometric parameters required by the model. GEOM also computes the regional weight from epicenter to station which determines the relative portions of the propagation path in stable or tectonic crustal media.
- WAMP--Normalizes all waves propagated in the model to the size of the event (in m_b units), and corrects them for event type (explosion or earthquake) and depth of focus. WAMP performs this function by calculating the expected log amplitude for each wave observation.
- SPROB--Calculates p_{ijk}, the probability that station i will observe wave k propagated from an event at epicenter j, for all (ijk) relevant to the particular run.
- ATSD--Computes the arrival-time standard deviation for each wave. The computation accounts for the advanced techniques used to obtain location estimates such as master-event calibration of P-wave arrivals and S-P time fix.
- SUBSET--Calculates all probabilities associated with station subsets. Thus, SUBSET calculates the probability that the network has met the pP step-out criteria. For SNAP/I, SUBSET

would calculate the probability that the network has satisfied the first-motion discriminant criteria.

- LOCATE--Calculates the area of the epicentral estimate error ellipse, the length of the depth confidence interval, and the importance of wave/station combinations at user-specified epicenters.
- PRINT--Controls and formats the output of SNAP/D.

SNAP/D performs two largely independent sets of computations. If the user selects a detection contour printout alone, then the ATSD and LOCATE modules are inoperative for that run. On the other hand, if the user selects only a location contour printout for a specified event size, then TRANS, NPROB, and BINMB are inoperative for that run. If the user selects both sets of computations, he may perform location calculations for each epicenter at the detection threshold magnitude (in m_b units).

III. INPUTS

This section summarizes the inputs to SNAP/D. Part II details the interactive format in which they are used. However, the user should familiarize himself with the material presented here before attempting to run SNAP/D, since the interactive prompts in Part II are too brief to completely describe the function, units, range, etc., of each input.

The input categories and file structure described below conform to the convention used for interactive prompting. When a file is indicated, the corresponding data may be stored and recalled for use with or without review or updating. The input categories are

- Control inputs--Nonnumerical information that defines the nature of the run.
- Detection input file--A short file that provides the multiwave network detection criteria and associated parameters for runs computing detection contours.
- Topographic inputs--Inputs that require specification on a world map. Topographic inputs are filed in the following five categories:
  - Station file: Locates and statistically describes each station in the seismic network.
  - Epicenter grid file: Provides the set of test epicenters, which may or may not be broken into discontiguous blocks.
  - Epicenter/station calibration file: Lists the set of station indices that are master-event and S-P calibrated with respect to each epicenter index. *For consistent indexing, each epicenter/station calibration file must be cross-referenced to a given pair of station and epicenter grid files.*
  - Regional grid file: Provides stable/tectonic and Lg squelch weights with a simplified default mechanism.
  - Importance-matrix file: Determines the sets of epicenters for which wave/station importance values will be calculated.

- Wave inputs--Inputs that pertain to the waves listed in Table 1 (p. 8). The inputs for each wave are filed under the name of the wave. Each wave input file contains subfiles for each attenuation, travel-time, or travel-time standard-deviation table, as required.

Recall that each SNAP/D run, as established by the control inputs, is for a specific event/depth combination: an explosion (X) at 0 km depth, a shallow earthquake ($Q_{\bar{D}}$) at 15 km depth, or a deep earthquake (Q_D) at 100 km depth. Table 1 (p. 8) shows that some waves are not generated by a particular event. Thus, certain inputs are required for certain event types and not others--as indicated in the descriptions provided below. Furthermore, input values may depend on event type; thus, the user must indicate the relevant event in each file description.

In presenting the inputs below, we have followed the same sequence and terminology used for the SNAP/D interactive prompting. However, the discussions have been expanded to give the user a better understanding of the nature and function of each input.

CONTROL INPUTS

Select one option for each of the following inputs:

1. Calibration mode:
   - D, detection only
   - L, location only
   - DL, detection and location
2. Event type:
   - X, explosion at 0 km
   - $Q_{\bar{D}}$, shallow earthquake at 15 km
   - Q_D, deep earthquake at 100 km

3. Detection output option for D and DL runs:

   MAG, magnitude contours for fixed network-detection probability

   PR, probability contours for fixed magnitude value

4. Will importance-matrix calculations be required?

   Yes or no.

DETECTION INPUT FILE

Since the detection inputs are filed, the user may create new files or review and update old ones. Detection inputs are required for only D or DL runs.

1. Name and description of the file.
2. The detection criteria. (User is alerted at this point if an inadmissible criterion is entered.) For example (in interactive format):

   a. ((P + PG)*LG)/2 + (P)/4, with the literal meaning, (P *or* Pg) *and* Lg observed by at least two stations, *or* P observed by at least four stations.

   b. (P)/4, meaning, at least a four-station P-wave observation.

   c. (R)/2, meaning, at least a two-station Rayleigh-wave observation.

If output option MAG was chosen in control inputs, the user now enters

3. P_T, the probability threshold for magnitude contours in either m_b units for multiwave or P-wave-only detection criteria (examples a and b above), or in m_k units for single-wave detection criteria involving wave k (e.g., magnitude contours in M_s units, such as example c above).
4. M_{min}, the lowest magnitude used in the binary search in m_b or m_k units, as above.
5. M_{max}, the highest magnitude used in the binary search in m_b or m_k units, as above.

If output option PR was chosen in control inputs, the user now enters

6. M_T, the magnitude threshold in either m_b units (examples a and b above), or m_k units (example c above).

TOPOGRAPHIC INPUTS

Topographic inputs consist of one file from each of the following five categories: station files, epicenter grid files, epicenter/station calibration files, regional grid files, and importance-matrix files. Users should have a map of the relevant area available before creating any of those files, since correspondence of station, epicenter, and regional grid indexing with geographical coordinates is essential for proper operation of SNAP/D.

Station File

The first seven of the following inputs apply to all stations in the network. Amplitude units are 0-P mμ.

1. Name and description of the file.
2. N, the number of stations in the seismic network.
3. μ_{nk}, the mean of the lognormally distributed noise level for wave k at all stations, k = 1, ..., 10.
4. σ_{nk}, the standard deviation (s.d.) of $\log_{10}$ noise amplitude for wave k at all stations.
5. σ_{sk}, the s.d. of $\log_{10}$ signal amplitude for wave k at all stations for a given magnitude m_k, in the magnitude units for wave k.
6. σ_{bk}, the additional s.d. of $\log_{10}$ signal amplitude for wave k at all stations, given an m_b value. This input is not requested for the P wave (k = 1).
7. r_k, the signal-to-noise ratio (SNR) required to observe wave k at all stations.

The inputs for station i, i = 1, ..., N, are

8. Name and station, four letters maximum.
9. (θ_i, ϕ_i), the latitude and longitude of station i. θ_i is in degrees north or south of the equator, and ϕ_i is in degrees east or west of Greenwich meridian.
10. R_i, the reliability of station i. This is the probability that station i is operational at any time.
11. μ_{nik}, the mean noise level for wave k at station i.

If $\mu_{nik} = 0$, *then noise level is* μ_{nk};
if $\mu_{nik} \neq 0$, *then noise level is* μ_{nik}.

12. σ_{nik}, the $\log_{10}$ noise s.d. for wave k at station i.

If $\sigma_{nik} = 0$, *then noise s.d. is* σ_{nk};
if $\sigma_{nik} \neq 0$, *then noise s.d. is* σ_{nik}.

13. σ_{sik}, the $\log_{10}$ signal s.d. for wave k at station i.

If $\sigma_{sik} = 0$, *then signal s.d. is* σ_{sk};
if $\sigma_{sik} \neq 0$, *then signal s.d. is* σ_{sik}.

14. r_{ik}, the SNR required to observe wave k at station i.

If $r_{ik} = 0$, *then SNR is* r_k;
if $r_{ik} \neq 0$, *then SNR is* r_{ik}.

15. s_{ik}, the station-dependent arrival-time s.d. for wave k at station i, k = 1, 2, 5.
16. $\sigma_{\beta i}$, the s.d. of the Lg (k = 3) back azimuth estimate error at station i.

<u>Epicenter Grid File</u>

1. Name and description of the file.
2. H, the number of epicenter blocks. Blocks may be used to provide discontiguous epicenter grids in a single run (e.g.,

NTS and USSR), or to provide additional density of test epicenters within a large geographical region.

3. $J_\theta^{(h)}$, the number of epicenter latitudes for block h.
4. $J_\phi^{(h)}$, the number of epicenter longitudes for block h.
   - $J^{(h)} = J_\theta^{(h)} J_\phi^{(h)}$ is the total number of epicenters in block h.
   - $J = \sum_{h=1}^{H} J^{(h)}$ cannot exceed 400.
5. $\theta_1^{(h)}$, the starting latitude.
6. $\Delta\theta^{(h)}$, the latitudinal distance between epicenters.
7. $\phi_1^{(h)}$, the starting longitude.
8. $\Delta\phi^{(h)}$, the longitudinal distance between epicenters.

Epicenter indexing proceeds as

$$[\theta_1^{(1)}, \phi_1^{(1)}], [\theta_1^{(1)}, \phi_1^{(1)} + \Delta\phi^{(1)}], \ldots,$$

$$[\theta_1^{(1)}, \phi_1^{(1)} + J_\phi^{(1)} \Delta\phi^{(1)}], [\theta_1^{(1)} + \Delta\theta^{(1)}, \phi_1^{(1)}], \ldots,$$

$$[\theta_1^{(1)} + J_\theta^{(1)} \Delta\theta^{(1)}, \phi_1^{(1)} + J_\phi^{(1)} \Delta\phi^{(1)}], [\theta_1^{(2)}, \phi_1^{(2)}], \ldots .$$

Epicenter/Station Calibration File

1. Name and description of the file. To avoid indexing errors, the description should cross-reference the station and epicenter grid files for the relevant calibration inputs.
2. ϵ_{ijk}, the magnitude correction for station i, epicenter j, and wave k. Defaults to $\epsilon_{ijk} \equiv 0$ for nonentries.
3. Ω_j, the set of stations (i.e., station indices) that are master-event calibrated with respect to an event at epicenter j.
4. ψ_j, the set of stations that are S-P calibrated with respect to an event at epicenter j.

Since Ω_j and ψ_j, the sets of calibrated stations for epicenter j, may depend on the focal depth of the event, the user must indicate in the calibration file name or description whether the file pertains to a shallow (X or $Q_{\bar{D}}$) or deep (Q_D) event.

Regional Grid File

Each regional grid file covers the entire globe. Thus, the same file can be used with any epicenter file. However, the user is asked to enter weights for only nonstable ($w_\ell \neq 0$) and Lg squelching ($v_\ell \neq 0$) grids. All other grid weights default to $w_\ell = 0$ and $v_\ell = 0$.

1. Name and description of the file.
2. Δ_R, the grid dimension.
   - Individual grids have equiangular sides so that $\Delta\theta = \Delta\phi = \Delta_R$.
   - In general, $2° \leq \Delta_R \leq 10°$.
3. $\Delta\theta_c$, the size of polar caps in degrees latitude.
   - Because of the increasing density of grids near the poles, the polar caps are assigned a single regional weight.
   - The starting latitude for generating the first regional grid is $\theta_{R1} = 90° - \Delta\theta_c$ south of the equator. The starting longitude is $\phi_{R1} = 180°$.
   - $180° - 2\Delta\theta_c$ and $360°$ must be multiples of Δ_R.
4. w_N, the regional weight for the north polar cap, $0 \leq w_N \leq 1$.
5. w_S, the regional weight for the south polar cap, $0 \leq w_S \leq 1$.
6. w_ℓ, $\ell = 1, \ldots, L_R$, the weight assigned to each regional grid excluding the polar caps.
   - $0 \leq w_\ell \leq 1$, where $w_\ell = 0$ implies a purely stable geology for the *ℓth* grid, and $w_\ell = 1$, purely tectonic. If no weight is entered, the program defaults to $w_\ell = 0$.
   - $L_R = (360°/\Delta_R)(180° - 2\Delta\theta_c/\Delta_R)$.

7. v_ℓ, $\ell = 1, \ldots, L_R$, the squelch weight for Lg waves.

   - $v_\ell = 0$ or 1, where $v_\ell = 1$ implies that Lg waves are squelched in the *ℓth* grid, and $v_\ell = 0$ implies no squelching. The interactive prompts for SNAP/D simply request the indices of the grid for which $v_\ell = 1$.

Importance-Matrix File

If importance-matrix calculations were requested, the user must now specify the epicenters to which the calculations will apply. An output matrix is provided for each input set of epicenters.

1. Name and description of the file.
2. Γ_m, m = 1, ..., M, the set of epicenter indices for the *mth* output importance matrix.

   - As a special case, the user may request an importance-matrix output for all epicenters without actually enumerating them.

WAVE INPUTS

The wave inputs consist of a common-wave file and a file for each individual wave. The common-wave file requires the following entries:

1. Name and description of the file.
2. m_{bL}, the m_b value used for all location and importance calculations.

- *If $m_{bL} = 0$, then SNAP/D defaults to using threshold detection magnitude for calculating wave observation probabilities at each station for a given epicenter. However, it is inadmissible to set $m_{bL} = 0$ for an L run, or for D or DL runs not using the P wave in the detection criteria. Also, m_{bL} should not be set to zero if a fixed-magnitude run is requested (i.e., the output option PR was chosen in control inputs).*

3. P_c, the confidence probability associated with error ellipse and depth-interval calculations, in multiples of 5 percent.

4. The indices of the waves that are to be *excluded* from location and importance calculations (the effect of excluding a wave is simply to zero out its amplitude in SNAP/D).
5. The names of the wave files for waves that will be used for either location or detection.

The individual wave file inputs are given below. All attenuation, travel-time, and travel-time s.d. tables are in files that have entries in the standard (i.e., NETWORTH [Wirth, 1977]) format.

P-Wave File

1. Name and description of the file.
2. Stable media attenuation file with table entries starting at $\Delta = 0°$.
   - The P-wave stable media attenuation file name should indicate whether the attenuation table applies to a shallow or deep event, since the shallow attenuation table starts with the Pn phase.
3. Tectonic media attenuation file for $\Delta \leq 20°$.
4. Travel-time file for starting at $\Delta = 0°$.
   - The travel-time file name should indicate whether the table is applicable to a shallow or deep event.
5. Travel-time s.d. file.
6. σ_{0k}, k = 1, P-wave arrival-time reading error s.d.
7. $v_p(z)$, the P-wave velocity at z = 0, 15 or 100 km.
   - Since different travel-time tables apply to shallow and deep events, and v_P is a function of depth, the user must indicate in the P-wave file name or description whether the file applies to an X, $Q_{\bar{D}}$, or Q_D event. For the Q_D event, the tectonic media attenuation file is not required.

Pg-Wave File

The Pg wave is not generated by a Q_D event.

1. Name and description of the file,
2. Stable media attenuation file.
3. Tectonic media attenuation file ($\Delta \leq 20°$).
4. Travel-time file.
5. Travel-time s.d. file,
6. $[KE]_{k=2}^{(\alpha)}$, event/depth normalization constants for stable ($\alpha = S$) and tectonic ($\alpha = T$) media.
7. $[KM]_{k=2}^{(\alpha)}$, magnitude normalization constants for stable ($\alpha = S$) and tectonic ($\alpha = T$) media.

   - The use of $[KE]_{k=2}^{(\alpha)}$ and $[KM]_{k=2}^{(\alpha)}$ is explained in Sec. IV, during discussion of the WAMP module.

8. σ_{0k}, $k = 2$.

Lg-Wave File

The Lg wave is not generated by a Q_D event. Since the Lg event factor $[KE]_{k=3}^{(\alpha)}$ is different for the X and $Q_{\bar{D}}$ events, the Lg-wave file name or description should indicate which of these events is desired.

1. Name and description of the file.
2. Stable media attenuation file.
3. Tectonic media attenuation ($\Delta \leq 20°$)
4. $[KE]_{k=3}^{(\alpha)}$, $\alpha = S$ or T.
5. $[KM]_{k=3}^{(\alpha)}$, $\alpha = S$ or T.

S-Wave File

The S wave is generated by all events, but is used for location calculations only if the epicenter/station pair is S-P calibrated. In that case, the arrival-time error is deduced from the P-arrival errors, thus eliminating the need for S-wave travel-time and travel-time s.d. tables. Since $[KE]_{k=4}^{(\alpha)}$ is event-dependent, the S-wave file name or description should indicate the relevant event. For the Q_D event, the tectonic media attenuation file is not required.

1. Name and description of the file.
2. Stable media attenuation file.
   - S-wave stable media attenuation table must indicate whether the attenuation table applies to a shallow or deep event, since the shallow attenuation table starts with the Sn phase.
3. Tectonic media attenuation file ($\Delta \leq 20°$).
4. $[KE]_{k=4}^{(\alpha)}$, $\alpha = S$ or T.
5. $[KM]_{k=4}^{(\alpha)}$, $\alpha = S$ or T.
6. σ_{0k}, $k = 4$.
7. v_P/v_S, the ratio of P-to-S-wave velocities for S-P calibrated paths.

<u>pP-Wave File</u>

The pP wave is generated in SNAP/D only by a Q_D event.

1. Name and description of the file.
2. Attenuation file.
3. Travel-time file.
4. Travel-time s.d. file.
5. $[KE]_{k=5}$.
6. $[KM]_{k=5}$.
7. σ_{0k}, $k = 5$.

The following three inputs are used by the SUBSET module as explained in Sec. IV.

8. L, the total number of step-out rings.
9. L_s, the minimum number of detecting rings required to satisfy step-out criteria.
10. Δ_ℓ, $\ell = 1, \ldots, L$, the minimum radius of ring ℓ.

<u>Rayleigh-Wave File</u>

The Rayleigh wave is not used for location. The file name or description should indicate the relevant event type.

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1. Name and description of the file.
2. Attenuation table.
3. $[KE]_{k=6}$.
4. $[KM]_{k=6}$.

IV. MICROSTRUCTURE

This section summarizes the calculations performed by each SNAP/D module. We begin with a review of the different computational sequences initiated by the user during the interactive session.

If the run mode is detection only, then ATSD and LOCATE are not used, and the only waves propagated are those included in the detection criteria. If the run mode is location only, TRANS and BINMB are not used, and all waves for the selected event type are propagated (see Table 1, p. 8), except those excluded by the user in the common-wave inputs.

If the magnitude contours for a fixed probability threshold are desired, then a binary search is carried out (under the direction of BINMB), in the feedback loop consisting of BINMB, WAMP, SPROB, and TRANS (see Fig. 1, p. 11). If the user requests probability contours, then BINMB is not used.

Location calculations are performed either at the user-specified magnitude m_{bL}, or, if the user enters $m_{bL} = 0$, at the detection threshold, magnitude for each epicenter. Hence, the user should not set $m_{bL} = 0$ if (1) the run is for location only; (2) probability contours are requested for the detection output (i.e., output option PR was chosen); (3) the P wave is not included in the detection criteria.

It is essential that the user select commensurate input files. The epicenter/station calibration file requires cross-referencing of the station and epicenter indices for the proper operation of SNAP/D. Furthermore, wave files are generally relevant for a specific event type only. The user will receive ample warning of those contingencies during interactive prompting.

Because of the abundance of symbols and indices required to describe the mathematical manipulations performed by SNAP/D, the module discussions in this section will occasionally share symbols. However, the following indexing system remains constant:

i = station index,

j = epicenter index,

k = wave index.

Finally, we again note that the partitioning of SNAP/D into modules is conceptual. The correspondence of modules with subroutines in the computer program is discussed in Part II. Module descriptions follow below.

EGRID

SNAP/D performs all computations on an epicenter-to-epicenter basis. The function of EGRID is to step the program from one epicenter to another according to the sequence listed on p. 19 of Sec. III. EGRID requires the inputs in the epicenter grid file, and the EGRID output is (θ_{Ej}, ϕ_{Ej}), the location of epicenter j for $j = 1, 2, \ldots, J$.

GEOM

Given the location of the epicenter j, $(\tilde{\theta}_{Ej}, \phi_{Ej})$,† and station i, $(\tilde{\theta}_i, \phi_i)$, GEOM calculates the epicentral angular distance Δ_{ij}, and azimuth α_{ij} (measured positive clockwise from north), from the great-circle geometric relations [Beyer, 1978]:

$$\cos \tilde{\theta}_i = \sin \tilde{\theta}_{Ej} \cos \alpha_{ij} \sin \Delta_{ij} + \cos \tilde{\theta}_{Ej} \cos \Delta_{ij} \tag{1}$$

and

$$\tan(\phi_i - \phi_{Ej}) = \frac{\sin \alpha_{ij} \sin \Delta_{ij}}{\sin \tilde{\theta}_{Ej} \cos \alpha_{ij} - \cos \tilde{\theta}_{Ej} \sin \Delta_{ij} \cos \alpha_{ij}} . \tag{2}$$

After some manipulations of Eqs. (1) and (2), we obtain

†Given a latitude θ in standard geographic convention (i.e., $\theta = 0$ at the equator and positive north), $\tilde{\theta} = \pi/2 - \theta$. The use of the polar coordinate $\tilde{\theta}$ simplifies the expressions in the discussion of GEOM. The longitude ϕ is the same in the two conventions.

$$\cos \Delta_{ij} = \sin \tilde{\theta}_{Ej} \sin \tilde{\theta}_i \cos (\phi_i - \phi_{Ej}) + \cos \tilde{\theta}_{Ej} \cos \tilde{\theta}_i$$

and

$$\tan \alpha_{ij} = \frac{\sin \tilde{\theta}_{Ej} \sin (\phi_i - \phi_{Ej})}{\sin \tilde{\theta}_{Ej} \cos \phi_i - \cos \tilde{\theta}_{Ej} \sin \tilde{\theta}_i \cos (\phi_i - \phi_{Ej})} .$$

For shallow events with $\Delta_{ij} \leq 20$ deg, GEOM also calculates W_{ij}, the ratio of the length of the epicenter-to-station path in tectonic media to the total great-circle pathlength Δ_{ij}. This calculation begins by determining the pathlength traversed from epicenter to station in each regional grid. For every grid boundary longitude ϕ', between ϕ_{Ej} and ϕ_i, the distance from the epicenter to that longitude along the propagation path is, from Eqs. (1) and (2),

$$\tan \Delta' = \frac{\tan (\phi' - \phi_{Ej}) \sin \tilde{\theta}_{Ej}}{\tan (\phi' - \phi_{Ej}) \cos \tilde{\theta}_{Ej} \cos \alpha_{ij} + \sin \alpha_{ij}} . \qquad (3)$$

Likewise, for every grid boundary latitude $\tilde{\theta}^* < \tilde{\theta}_{Ej}$ if $\alpha_{ij} < |\pi/2|$, and $\tilde{\theta}^* > \tilde{\theta}_{Ej}$ if $\alpha_{ij} > |\pi/2|$, the distance from the epicenter to that latitude along the propagation path is

$$\tan \Delta^* = \frac{\cos \tilde{\theta}^* \sin \tilde{\theta}_{Ej} \cos \alpha_{ij} \pm \cos \sqrt{Q}}{\cos \tilde{\theta}^* \cos \tilde{\theta}_{Ej} \mp \sin \tilde{\theta}_{Ej} \cos \alpha_{ij} \sqrt{Q}} , \qquad (4)$$

where

$$Q = \sin^2 \tilde{\theta}_{Ej} \cos^2 \alpha_{ij} + \cos^2 \tilde{\theta}_{Ej} - \cos^2 \tilde{\theta}^* .$$

Since it is possible to cross a regional grid latitude $\tilde{\theta}^* < \tilde{\theta}_i$ if $\alpha_{ij} < |\pi/2|$, or $\tilde{\theta}^* > \tilde{\theta}_i$ if $\alpha_{ij} > |\pi/2|$, all real solutions of Eq. (4) represent admissible regional grid boundary crossings unless $\Delta^* < \Delta_{ij}$.

Now place the $\{\Delta'\}$ from Eq. (3) and the admissible $\{\Delta^*\}$ from Eq. (4) in ascending order to form the set Δ_u, $u = 1, \ldots, U$. Let

$\Delta_0 \equiv 0$ and $\Delta_{U+1} \equiv \Delta_{ij}$. Then, the *uth* path segment length is $\delta_u = \Delta_u - \Delta_{u-1}$. Equations (1) and (2) can now be used to find the index of the regional grid that contains the *uth* path segment; let w_u be the weight associated with this grid. All path segments in the polar cap regions ($\theta' < \Delta\theta'_c$ or $\theta' > \pi - \Delta\theta'_c$) are assigned the respective polar cap weights w_N or w_S. Then

$$W_{ij} = \frac{\sum_{u=1}^{U+1} w_u \delta_u}{\Delta_{ij}} \, ,$$

Since $0 \leq w_u \leq 1$ and $\sum \delta_u = \Delta_{ij}$, then $0 \leq W_{ij} \leq 1$. A similar procedure is used to determine $\{v_u\}$, the set of Lg squelch weights for the epicentral path. Then

$$V_{ij} = \sum_{u=1}^{U+1} v_u \, ,$$

since $v_u = 0$ or 1, $0 \leq V_{ij} \leq U + 1$. If $V_{ij} \neq 0$, then the epicentral path is assumed to have traversed a region that severely attenuates Lg waves. Thus, if $V_{ij} \neq 0$, the Lg wave is not propagated for that epicenter/station pair (i.e., $p_{ij3} \equiv 0$). If $V_{ij} = 0$, the propagation of the Lg wave is unaffected by the squelch weights.

WAMP

For a given epicenter j and m_b value, WAMP calculates $\log_{10} A_{ijk}$, the mean of the logarithmic amplitude of wave k observed at station i. In general,†

---

†Although b_k and c_k factors are tabulated by degrees in wave attenuation tables, the Δ_{ij} in Eq. (5) are converted to kilometers in SNAP/D.

$$\log_{10} A_{ijk}^{(\alpha)} = [KE]_k^{(\alpha)} + [KM]_k^{(\alpha)} m_b + b_k^{(\alpha)}(\Delta_{ij}) + c_k^{(\alpha)}(\Delta_{ij}) \log_{10} \Delta_{ij} + \varepsilon_{ijk} \tag{5}$$

is calculated for both stable (α = S) and tectonic (α = T) media. The event and magnitude factors $[KE]_k^{(\alpha)}$ and $[KM]_k^{(\alpha)}$, respectively, are used to convert an m_b value into an m_k value in the magnitude units of wave k. Thus,

$$m_k = [KE]_k^{(\alpha)} + [KM]_k^{(\alpha)} m_b$$

and, by definition, $[KE]_{k=1}^{(\alpha)} = 0$ and $[KM]_{k=1}^{(\alpha)} = 1$. If a single wave detection criterion is used, the above expression is substituted into Eq. (5). The $b_k^{(\alpha)}(\Delta_{ij})$ and $c_k^{(\alpha)}(\Delta_{ij})$ in Eq. (5) are the standard attenuation table entries, and ε_{ijk} is the epicenter/station calibration correction term for wave k.

If wave k does not require regional attenuation, or if $\Delta_{ij} > 20°$, then $\log_{10} A_{ijk}$ is computed directly from Eq. (5) using the stable media attenuation table--the only table available for waves not regionally attenuated and having entries for $\Delta_{ij} > 20°$ if the wave is regionally attenuated. Otherwise,

$$\log_{10} A_{ijk} = (1 - W_{ij}) \log_{10} A_{ijk}^{(S)} + W_{ij} \log_{10} A_{ijk}^{(T)} ,$$

where W_{ij} is the regional path weight computed by GEOM. As discussed in GEOM, if the Lg squelch weight over the propagation path is not zero, then, in effect, $\log_{10} A_{ij3} = -\infty$.

SPROB

SPROB computes p_{ijk}, the probability that wave k propagated from epicenter j will be observed at station i. The following statistical parameters are needed to compute p_{ijk}:

R_i, the reliability of station i.

μ_{nik}, the mean level of the lognormally distributed noise amplitude for wave k at station i.

σ_{nik}, the s.d. of the $\log_{10}$ noise amplitude for wave k at station i.

σ_{sik}, the s.d. of the $\log_{10}$ signal amplitude for wave k at station i for a given magnitude m_k, in the magnitude units for wave k.

σ_{bk}, the additional s.d. of the $\log_{10}$ signal amplitude for wave k, given an m_b value (hence, $\sigma_{b1} \equiv 0$).

r_{ik}, the SNR necessary for observation of wave k at station i.

$\log_{10} A_{ijk}$, the mean of the logarithmic amplitude of wave k, generated by epicenter j and observed at station i (as computed by WAMP).

Noting that both signal and noise are lognormally distributed, and making the conversion from natural to base 10 logarithms, SPROB calculates [Wirth, 1977]

$$p_{ijk} = R_i \Phi \left[\frac{\log_{10} A_{ijk} - 0.434\ (\ln \mu_{nik} + \ln r_{ik})}{\sqrt{\sigma_{nik}^2 + \sigma_{sik}^2 + \sigma_{bk}^2}} \right] , \qquad (6)$$

where

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-y^2/2}\, dy \ .$$

If the user specifies a detection criterion involving a single wave, then detection contours are computed for the magnitude units of that wave. In this case, $\sigma_{bk} \equiv 0$ in Eq. (6).

TRANS

The required notation for the TRANS and NPROB modules can be illustrated by an example of the user-entered detection criteria in an interactive format:

$$(P * LG)/2 + P/4 \ , \qquad (7)$$

which literally means that a network detection consists of at least a two-station observation of the P *and* (*) Lg waves, *or* (+) at least a four-station observation of the P wave. Expression (7) is said to consist of subcriteria (P * LG)/2 and P/4, which specify wave combinations $\mathcal{D}^1$ = P * LG and $\mathcal{D}^2$ = P, respectively.

The sequence of operations performed on detection criteria such as Eq. (7) falls into two categories. First, at the initiation of each run, the criteria are decomposed and reduced to a set of canonical probabilities. Second, at each epicenter, for a given m_b value, and with the help of the individual wave/station probabilities computed by SPROB, TRANS calls on NPROB to perform the canonical calculations. Those results are then used to compute the network detection probability, which is fed to BINMB.

The sequence of TRANS operations at the start of each SNAP/D run requiring detection contours consists of the following steps:

1. Interactively inform the user of syntax errors in the user-specified detection criteria. The error messages are covered in Part II of this report.
2. Reorder the subcriteria, the waves appearing in each wave combination, and the logical operations, so that the entire expression is in a standard format. For example:†

†The examples, taken directly from TRANS output, merely illustrate the operation of TRANS and have no operational significance.

a. PP/3 * S/1 + (PP + LG)/2 becomes (LG + PP)/2 * (S/1 * PP/3).

b. (LG + P * S + PP)/4 * (LG + P * S)/5 + (P * S + PP)/6 becomes (P * S + LG)/5 * (P * S + (LG + PP))/4 + (P * S + PP)/6.

3. Eliminate logical subsets among reordered subcriteria (i.e., remove redundant subcriteria), and reduce wave combinations to their simplest form. For example (from step 2):

   a. (LG + PP)/2 * (S/1 + PP/3) becomes S/1 * PP/3.

   b. (P * S + LG)/5 * (P * S + (LG + PP))/4 + (P * S + PP)/6 becomes (P * S + LG)/5 + (P * S + PP)/6.

4. Transform the reduced logical expression into an algebraic expression involving the marginal probabilities of independent subcriteria and the joint probabilities of dependent pairs of subcriteria. This transformation thus eliminates all logical "*ors*" among subcriteria by use of the elementary rule

$$\mathcal{P}[\mathcal{D}^1/n + \mathcal{D}^2/m] = \mathcal{P}[\mathcal{D}^1/n] + \mathcal{P}[\mathcal{D}^2/m] - \mathcal{P}[\mathcal{D}^1/n * \mathcal{D}^2/m] ,$$

   where, if $\mathcal{D}^1$ and $\mathcal{D}^2$ have no waves in common,

$$\mathcal{P}[\mathcal{D}^1/n * \mathcal{D}^2/m] = \mathcal{P}[\mathcal{D}^1/n]\mathcal{P}[\mathcal{D}^2/m] .$$

   For example (from step 3):

   a. $\mathcal{P}$[S/1 * PP/3] = $\mathcal{P}$[S/1]$\mathcal{P}$[PP/3].

   b. $\mathcal{P}$[(P * S + LG)/5 + (P * S + PP)/6]
      = $\mathcal{P}$[(P * S + LG)/5] + $\mathcal{P}$[(P * S + PP)/6]
      - $\mathcal{P}$[(P * S + LG)/5 * (P * S + PP)/6].

5. Interactively inform the user of an overdependency among subcriteria. Overdependency with respect to TRANS exists if and only if a wave combination has one or more waves in common with two or more other wave combinations within a probability argument after step 4. For example:

Suppose $\mathscr{D}^1$ has a wave in common with both $\mathscr{D}^2$ and $\mathscr{D}^3$, and step 4 resulted in the expression

$$\mathscr{P}[\mathscr{D}^1/n_1 * \mathscr{D}^2/n_2 * \mathscr{D}^3/n_3] .$$

The user would then be informed of an overdependency, and the run would be terminated.

6. Simplify the algebraic expression by adding and subtracting like terms. After this step, the user is interactively provided with the resulting expression.
7. Obtain and algebraically reduce the expression for the probability of observing the wave combination at a given station for each independent wave combination. Likewise, for each dependent pair of wave combinations, obtain and reduce expressions for the marginal probabilities of observing each wave combination, and the probability of observing both combinations jointly. For example (from step 5, example b):

   a. The expression is of the form

   $$\mathscr{P}[\mathscr{D}^1/5] + \mathscr{P}[\mathscr{D}^2/6] - \mathscr{P}[\mathscr{D}^1/5 * \mathscr{D}^2/6] .$$

   The probability of observing $\mathscr{D}^1$ at station i is

   $$p_i = p_{i1}p_{i4} + p_{i3} - p_{i1}p_{i3}p_{i4} .$$

   The probability of observing $\mathscr{D}^2$ at station i is

   $$q_i = p_{i1}p_{i4} + p_{i5} - p_{i1}p_{i4}p_{i5} .$$

   The probability of observing $\mathscr{D}^1 * \mathscr{D}^2$ at station i is, after reduction,

   $$c_i = p_{i1}p_{i4} + p_{i3}p_{i5} - p_{i1}p_{i3}p_{i4}p_{i5} .$$

   The p_{ik} in the above expressions are the probabilities of observing wave k at station i for a given epicenter (we have suppressed the j) and m_b value.

This concludes the operations performed by TRANS at the start of a run requiring the computation of detection contours.

The next sequence of operations performed by TRANS is done for each m_b value at every epicenter. The sequence begins with the reception of $\{p_{ik}\}$, $i = 1, \ldots, N$, $k = 1, \ldots, K$, from SPROB. It concludes with the computation of the network detection probability P_D. As an intermediate step, TRANS calls on NPROB to compute the marginal probability of individual subcriteria and the joint probability of dependent pairs of subcriteria. The sequence proceeds as follows:

8. Compute the numerical value of $\{p_i\}$, $i = 1, \ldots, N$, associated with each individual term of the form $\mathcal{P}[\mathcal{D}/n]$ and $\{p_i, q_i, c_i\}$, $i = 1, \ldots, N$, associated with each joint term of the form $\mathcal{P}[\mathcal{D}^1/n * \mathcal{D}^2/m]$, using $\{p_{ik}\}$ from SPROB and the probability expressions from step 7.
9. Initiate a one-dimensional (1D) calculation for each individual term by supplying NPROB with the $\{p_i\}$ associated with that term. NPROB returns $\mathcal{P}[\mathcal{D}_{(n':N)}]$, $n' = 0, 1, \ldots, N$, the probability that *exactly* n' out of N stations observe wave combination $\mathcal{D}$. Clearly,

$$\mathcal{P}[\mathcal{D}/n] = \sum_{n'=n}^{N} \mathcal{P}[\mathcal{D}_{(n':N)}] ,$$

   which is computed by TRANS for each individual term in the expression resulting from step 6.
10. Initiate a two-dimensional (2D) calculation for each joint term by supplying NPROB with the $\{p_i, q_i, c_i\}$ associated with that term. NPROB returns $\mathcal{P}[\mathcal{D}^1_{(n':N)} * \mathcal{D}^2_{(m':N)}]$, the probability that *exactly* n' out of N, and m' out of N, stations observed both $\mathcal{D}^1$ and $\mathcal{D}^2$, respectively. Clearly,

$$\mathcal{P}[\mathcal{D}^1/n * \mathcal{D}^2/m] = \sum_{n'=n}^{N} \sum_{m'=m}^{N} \mathcal{P}[\mathcal{D}^1_{(n':N)} * \mathcal{D}^2_{(m':N)}] ,$$

    which is computed by TRANS for each joint term in the expression resulting from step 6.

11. Calculate P_D from the results of steps 6, 9, and 10.

NPROB

Each call to NPROB produces one of two types of canonical probability calculations for TRANS. The calculations, many of which may be required for each m_b value at a given epicenter, include generalizations of 1D and 2D discrete convolutions [Feller, 1968]. The 1D calculation is essentially the same procedure used in NETWORTH [Wirth, 1977]; the 2D calculation was developed to accommodate multiwave network detection criteria that use combinations of dependent wave arrivals at individual stations, as explained in the discussion of TRANS. The 2D convolution, performed without approximation, is the most computationally efficient procedure among the several tested for the 2D calculation.

1D Calculation

Provided by TRANS with the probabilities of observing a given wave combination $\mathscr{D}$ at each station, $\{p_i\}$, $i = 1, \ldots, N$, NPROB calculates $\mathscr{P}[\mathscr{D}_{(n:N)}]$, the probability of observing $\mathscr{D}$ at exactly n of the total N stations in the network. Since here we always refer to wave combination $\mathscr{D}$, we generally denote the probability of observing $\mathscr{D}$ at exactly n of $M \leq N$ stations with indices $\gamma_1, \ldots, \gamma_M$ by $P(n|\gamma_1, \ldots, \gamma_M)$, so that $\mathscr{P}[\mathscr{D}_{(n:N)}] = P(n|1, \ldots, N)$.

The general 1D convolution equation is given by

$$P(n|\gamma_1, \ldots, \gamma_M) = \sum_{u=u_1}^{u_2} P(u|\alpha_1, \ldots, \alpha_{M_1})P(n - u|\beta_1, \ldots, \beta_{M_2}) ,$$

where $M = M_1 + M_2$,

$u_1 = \max(0, n - M_2)$,

$u_2 = \min(n, M_1)$.

Note that the division of the M stations into the two sets of M_1 and M_2 stations is arbitrary if, and only if, the two sets are mutually exclusive and exhaustive with respect to the M-station set. We schematically represent the combining of station sets in the above expression by

$$\underbrace{(M_1) \qquad (M_2)}_{(M)} .$$

In order to show how NPROB calculates $P(n|1, \ldots, N)$, consider an $N = 8$ station network. At the first stage, calculate

$$P(n|i, i + 1) = \sum_{u=u_1}^{u_2} P(n|i)P(n - u|i + 1) , \qquad n = 0, 1, 2 ,$$

for $i = 1, 3, 5, 7$. Note that $P(1|i) = p_i$ and $P(0|i) = 1 - p_i$, $i = 1, \ldots, N$. At the second stage, calculate

$$P(n|1, \ldots, 4) = \sum_{u=u_1}^{u_2} P(n|1, 2)P(n - u|3, 4) , \quad n = 0, 1, \ldots, 4 ,$$

and similarly obtain $P(n|5, \ldots, 8)$. Finally, at the third stage, calculate

$$P(n|1, \ldots, 8) = \sum_{u=u_1}^{u_2} P(n|1, \ldots, 4)P(n - u|5, \ldots, 8) ,$$

$$n = 0, 1, \ldots, 8 .$$

This example is simplified by the fact that $N = 8$ is a power of two. Thus, the combining rule is represented by

Stage	Combinations of Stations
1	(1) (1) (1) (1) (1) (1) (1) (1)
2	(2) (2) (2) (2)
3	(4) (4)
	(8)

However, the general 1D convolution also allows for the combining of different sized sets of stations. Thus, NPROB would handle an N = 23 station network as follows:

Stage	Combinations of Stations
1	(1) (1) (1) (1) ••• (1) (1) (1)
2	(2) (2) ••• (2) (1)
3	(4) (4) (4) (4) (4) (3)
4	(8) (8) (7)
5	(16) (7)
	(23)

2D Calculation

TRANS initiates a 2D calculation by providing NPROB with the probabilities $\{p_i, q_i, c_i\}$, $i = 1, \ldots, N$, as defined in steps 7 and 10 of the TRANS subsection. NPROB then computes $\mathcal{P}[\mathcal{D}^1_{(n:N)} * \mathcal{D}^2_{(m:N)}]$, the joint probability of observing wave combinations $\mathcal{D}^1$ and $\mathcal{D}^2$ at *exactly* n and m stations, respectively, of the total of N stations. With $\mathcal{D}^1$ and $\mathcal{D}^2$ understood, we generally denote the probability of observing $\mathcal{D}^1$ at n, and $\mathcal{D}^2$ at m, of the $M \leq N$ stations with indices $\gamma_1, \ldots, \gamma_M$ as $P(n, m|\gamma_1, \ldots, \gamma_M)$. Thus,

$$\mathcal{P}[\mathcal{D}^1_{(n:N)} * \mathcal{D}^2_{(m:N)}] = P(n, m|1, \ldots, N) .$$

The 2D calculation begins with the computation of $P(n, m|i)$, $i = 1, \ldots, N$. We will need the following elementary set relations for events $\mathcal{G}_1$ and $\mathcal{G}_2$:

$$\overline{\mathcal{G}_1\mathcal{G}_2} = \overline{\mathcal{G}_1 + \mathcal{G}_2} \qquad \text{(De Morgan's Law)}$$

and

$$\mathcal{G}_1 = \mathcal{G}_1\mathcal{G}_2 + \mathcal{G}_1\overline{\mathcal{G}}_2 .$$

Letting $\mathscr{D}^k_{(i:1)} = \mathcal{G}_k$ and $\mathscr{D}^k_{(0:1)} = \overline{\mathcal{G}}_k$ for station i, we obtain

$$P(n, m|i) = \begin{cases} 1 - p_i - q_i + c_i , & n = m = 0 , \\ p_i - c_i , & n = 1, m = 0 , \\ q_i - c_i , & n = 0, m = 1 , \\ c_i , & n = m = 1 , \end{cases}$$

for $i = 1, \ldots, N$.

The general 2D convolution equation for combining station sets of size M_1 and M_2, $M = M_1 + M_2$, is

$$P(n, m|\gamma_1, \ldots, \gamma_M) = \sum_{u=u_1}^{u_2} \sum_{v=v_1}^{v_2} P(u, v|\alpha_1, \ldots, \alpha_{M_1})$$
$$\times P(n - u, m - v|\beta_1, \ldots, \beta_{M_2}) ,$$
$$n, m = 0, 1, \ldots, M ,$$

where $u_1 = \max(0, n - M_2)$,
$u_2 = \min(n, M_1)$,
$v_1 = \max(0, m - M_2)$,
$v_2 = \min(m, M_1)$.

Using this expression and $P(n, m|i)$ from above, NPROB combines station sets in the same manner as the 1D calculation. For example, at stage 1,

$$P(n, m|i, i+1) = \sum_{u=u_1}^{u_2} \sum_{v=v_1}^{v_2} P(u, v|i)P(n-u, m-v|i+1) ,$$

$$n = 0, 1, 2 ,$$

for $i = 1, 3, 5, \ldots$. Then, for stage 2,

$$P(n, m|1, 2, 3, 4) = \sum_{u=u_1}^{u_2} \sum_{v=v_1}^{v_2} P(u, v|1, 2)P(n-u, m-v|3, 4) ,$$

$$n = 0, 1, \ldots, 4 ,$$

etc., until $P(n, m|1, \ldots, N)$, $n, m = 0, 1, \ldots, N$, is obtained. The general combining scheme for arbitrary N is the same as that illustrated for the 1D calculation.

BINMB

BINMB directs the binary search for the magnitude value (generally in m_b units) that results in P_T, the user-specified threshold probability for network detection. Initially, BINMB selects $m_1 = M_{min}$, the user-specified minimum magnitude for the search. WAMP, SPROB, and TRANS then perform the calculations necessary to obtain $P_D(m_1)$, the network detection probability for magnitude m_1. If $P_D(m_1) < P_T$, then BINMB selects $m_2 = M_{max}$ and receives $P_D(m_2)$ from TRANS. If $P_D(m_2) > P_T$, then

$$m_3 = \frac{m_1 + m_2}{2} .$$

If $P_D(m_3) < P_T$, then

$$m_4 = \frac{m_3 + m_2}{2} ,$$

Otherwise,

$$m_4 = \frac{m_1 + m_3}{2} ,$$

etc., until

$$|P(m_v) - P_T| \leq 0.01$$

for some v. The threshold magnitude is then m_v, and the search is terminated.

ATSD

ATSD computes the arrival-time s.d. for all waves that provide the arrival-time data that LOCATE uses for computing the precision of the hypocenter estimate. Those waves include the P (k = 1), Pg (k = 2), S (k = 4), and pP (k = 5) waves. The Lg wave (k = 3) is also used for location. However, Lg observations provide back azimuth data rather than arrival-time data. The Rayleigh wave (k = 6) is not used for location.

The general expression for computing the arrival-time s.d. for wave k, propagated from epicenter j and observed at station i, is

$$\sigma_{ijk} = \left[\sigma_{0k}^2 + s_{ik}^2 + d_k^2(\Delta_{ij})\right]^{1/2} , \qquad (8)$$

where σ_{0k} is the reading-error s.d., s_{ik} is the station-dependent arrival-time s.d., and $d_k(\Delta_{ij})$ the travel-time s.d. table entry for wave k. The σ_{ijk} for the Pg and pP waves are computed from Eq. (8) without modification. However, the P and S waves require special

treatment because of the possibility of epicenter/station master-event or S-P calibration.

Recall that Ω_j is the set of indices for stations that are master-event calibrated with respect to epicenter j. The effect of calibrating the epicenter-to-station path is to reduce scatter in the P-wave arrival time [Čiervo, 1978]. However, the reading error is always present. Thus, for the P wave, ATSD computes $\sigma_{ij1} = \sigma_{01}$ if $i \in \Omega_j$; otherwise, σ_{ij1} is computed from Eq. (8).

The situation with respect to the S wave is more complex. The S wave is used for location only if station i is S-P calibrated with respect to epicenter j (i.e., if $i \in \psi_j$). Thus, if $i \notin \psi_j$, then LOCATE receives $p_{ij4} \equiv 0$, effectively eliminating the S wave from location calculations. If $i \in \psi_j$, then LOCATE considers the error in the datum to be composed of a linear combination of the P-arrival time (t_P) and the S-arrival time (t_S) given by

$$\tau = t_S - \left(\frac{v_P}{v_S}\right) \frac{\left[s_{i1}^2 + d_1^2(\Delta_{ij})\right]}{\sigma_{ij1}^2} t_P \ .$$

This particular combination of t_P and t_S is uncorrelated with respect to t_P, which simplifies the matrix algebra in LOCATE. The s.d. of τ is

$$\sigma_{\tau ij} = \left[\sigma_{04}^2 + \left(\frac{v_P}{v_S}\right)^2 \frac{\sigma_{01}^2\left(\sigma_{ij1}^2 - \sigma_{01}^2\right)}{\sigma_{ij1}^2}\right]^{1/2} \ . \qquad (9)$$

Thus, if $i \in \Omega_j$, then $\sigma_{ij1} = \sigma_{01}$ as discussed above, and $\sigma_{\tau ij} = \sigma_{04}$, the S-wave reading error. In the SNAP/D computer program, LOCATE is fed σ_{01}, σ_{04}, and v_P/v_S at the beginning of the run. Then, $\sigma_{\tau ij}$ is computed within LOCATE for each (i, j) from Eq. (9) using the value of σ_{ij1} supplied by ATSD.

SUBSET

The function of SUBSET is to perform all computations involving subsets of the entire N-station network. In SNAP/D, these include calibrations concerning the step-out phenomena for the reflected phase pP. In SNAP/I (planned for future development), SUBSET would also handle calculations for the "first-motion" discriminant [Ciervo, 1978].

The step-out requirement specifies that the pP wave must be observed over a range of epicentral distances in order to be correctly identified [Ciervo, 1978]. The identification process is simply to observe that the pP arrival lags farther behind the P arrival as epicentral distance increases (hence the term "step-out"). As shown in Fig. 2, SNAP/D models the step-out process by calculating the probability that the pP wave will be observed by at least one station in L_s of a total of L "rings" surrounding the epicenter. L_s, L, and Δ_ℓ, $\ell = 1, \ldots, L$, the minimum radius of ring ℓ, are all entered by the user into the pP-wave file. Stations for which $\Delta_{ij} < \Delta_1$ are assumed not to observe the pP wave.

Station i is said to be in ring ℓ if $\Delta_\ell \leq \Delta_{ij} < \Delta_{\ell+1}$, where Δ_{L+1} is, by definition, the distance corresponding to the last pP-wave attenuation table entry. Furthermore, ring ℓ is said to observe the pP wave if at least one station in ring ℓ observes it. Now define the events

$\mathfrak{J}_{ij}$: pP propagated from epicenter j is observed by station i ,

and

$\mathcal{S}_j$: L_S of L rings with respect to epicenter j observe the pP wave .

As computed by SPROB,

$$p_{ij5} = \mathcal{P}[\mathfrak{J}_{ij}] \; . \tag{10}$$

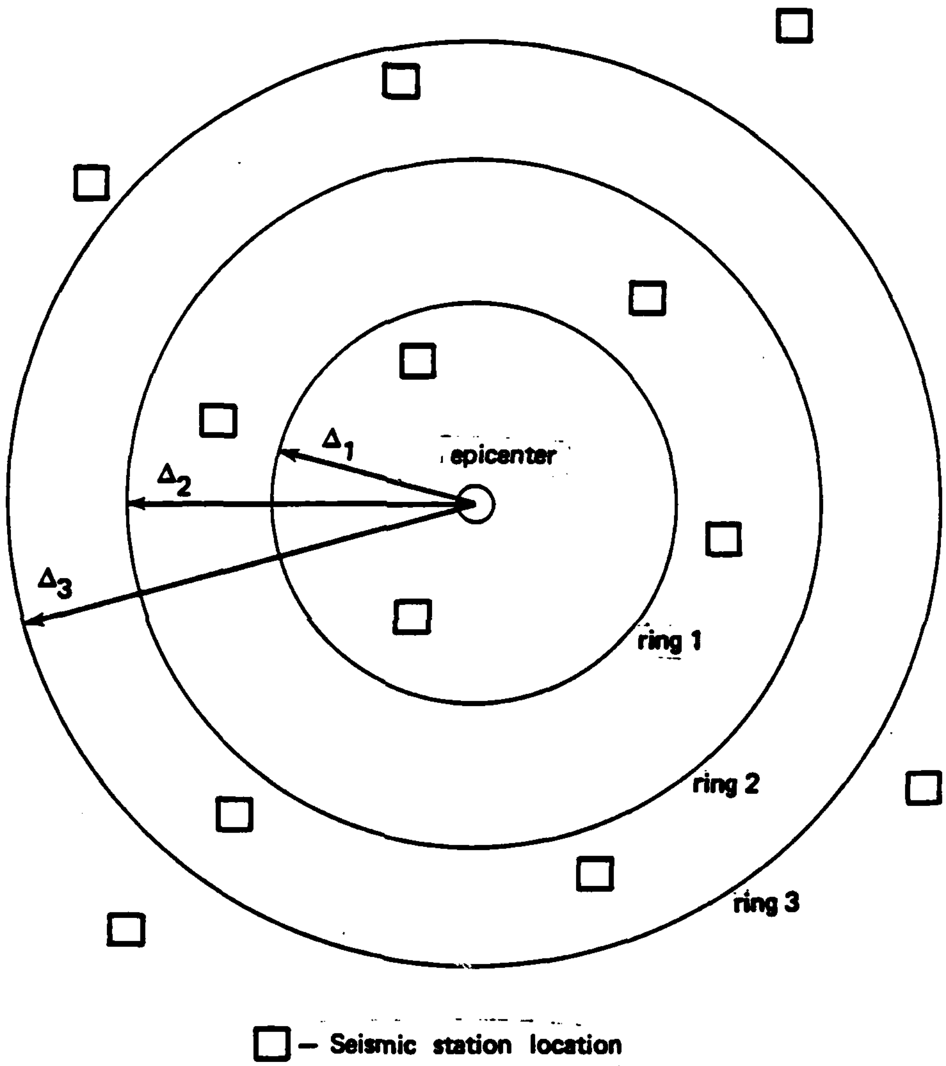

Fig. 2--Step-out rings for pP-wave observation

The function of SUBSET in SNAP/D is to calculate

$$\begin{aligned} p'_{ij5} &= \mathcal{P}[\mathfrak{I}_{ij}, \mathcal{S}_j] \\ &= \mathcal{P}[\mathfrak{I}_{ij}]\mathcal{P}[\mathcal{S}_j/\mathfrak{I}_{ij}] \\ &= p_{ij5}\mathcal{P}[\mathcal{S}_j/\mathfrak{I}_{ij}] \ . \end{aligned} \qquad (11)$$

In order to calculate $\mathcal{P}[\mathcal{S}_j/\mathfrak{I}_{ij}]$, we will also need to define Φ_ℓ as the set of indices for all stations in ring ℓ. Then the probability that ring ℓ observes the pP wave is

$$Q_\ell = 1 - \prod_{i \in \Phi_\ell} (1 - p_{ij5}) \ , \qquad \ell = 1, \ldots, L \ .$$

The conditioning in the expression $\mathcal{P}[\mathcal{S}_j/\mathfrak{I}_{ij}]$ ensures that the ring containing station i—call it ring ℓ'—observed the pP wave. Thus, $\mathcal{P}[\mathcal{S}_j/\mathfrak{I}_{ij}]$ is the probability of $L_S - 1$ "successes" out of $L - 1$ "trials," where the $L - 1$ trials have the success probabilities $Q_1, \ldots, Q_L$, *excluding* $Q_{\ell'}$. This probability is identical to that computed by the 1D calculation in NPROB. Thus, SUBSET calls NPROB with the set $\{Q_\ell\}$, $\ell = 1, \ldots, L$, excluding ℓ', and receives back

$$\mathcal{P}[\mathcal{S}_j/\mathfrak{I}_{ij}]$$

as the probability of exactly $L_S - 1$ successes in $L - 1$ trials. Then p'_{ij5} is calculated from Eq. (11). For a given epicenter j, the p'_{ij5}, $i = 1, \ldots, N$, are then used *instead of* the p_{ij5}, $i = 1, \ldots, N$, for the computations in TRANS and LOCATE.

<u>LOCATE</u>

For epicenter j, LOCATE calculates A_j, the area of the epicentral estimate uncertainty ellipse; and d_j, the length of the depth-estimate

confidence interval at P_c, the user-specified confidence probability. For each set of epicenter indices, Γ_m, m = 1, ..., M, LOCATE also calculates the minimum, maximum, and average importance values for each station/wave pair. The inputs required by LOCATE for each epicenter are $\{p_{ijk}\}$, $\{\sigma_{ijk}\}$, $\{\sigma_{\beta i}\}$, $\{\Gamma_m\}$, $\{\Delta_{ij}\}$, $\{\alpha_{ij}\}$, v_P, v_P/v_S, P_c, and the travel-time tables for the relevant waves.

LOCATE, a complex computer model by itself, was developed by Systems, Science and Software, which supplied the general description provided in the Appendix.

PRINT

The function of PRINT is to format the output of SNAP/D. The types of output are determined by the user during the interactive session at the initiation of each run. Since much of the useful output for each run is the input material itself, the user may wish to have a printout of the entire CRT interactive session. The user may also elect to have all table (e.g., travel time and attenuation) entries--material that would not be seen if input files were called without review or update--printed out for any selected wave. In addition, summary information or detailed results may be printed out for each epicenter.

SNAP/D output consists of three sections. The first section identifies the run mode (detection, location, or both); provides the network probability expression; and, depending on the mode, gives the threshold magnitude, probability, or percent confidence level for the ellipses. These are followed by the user's file descriptions of every file used.

The second section consists of station and wave tables. The station tables are printed one table per wave. Each contains the station index, name, and location; and the station-noise amplitude and s.d., followed by the signal-to-noise ratio, arrival-time s.d., station reliability, and signal s.d.

Next, the set of wave tables, if requested, is printed by wave type. Three types of table are included: (1) stable and tectonic (if applicable) attenuation tables, which list angular distance in degrees, b-factors, and c-factors; (2) the travel-time table, which contains distance in degrees followed by the number of seconds needed to traverse that distance; (3) the travel-time s.d. table, which lists angular distances in degrees, followed by travel-time standard deviations in seconds.

The third section (optional) consists of the SNAP/D calculations for each epicenter. The first line of the detailed epicenter output lists epicenter number, location, and threshold magnitude for network detection. The second line lists station-specific data for each epicenter. Those consist of station index and name, angular distance, and azimuth. Also included for each wave used is the s.d. of arrival time (zero if the run is for detection only), and probability of observation (p_{ijk}) for the given station, epicenter, and wave combination.

Regardless of whether a detailed epicenter output is elected, a network-detection summary table will be printed if the run is for detection only, detection and location with $m_{bL} \neq 0$, or detection and location with $m_{bL} = 0$ and probability contours requested. The heading of this table lists the threshold magnitude or probability, and the binary-search magnitude range for a threshold magnitude. Table entries consist of epicenter number, location, and threshold magnitude or probability.

For a location or detection/location run, a network-location summary table is presented next. The heading of such a table shows the binary-search magnitude range if $m_{bL} = 0$. The columns of the table consist of epicenter index, location, detection magnitude (equal to m_{bL}, or threshold magnitudes if $m_{bL} = 0$), the lengths of the semimajor and semiminor ellipse axes, strike, ellipse area, and depth-interval length.

If importances are calculated, those tables are presented last. They are headed by importance-set index and consist of station index and the minimum, average, and maximum importance values for each

station/wave used for location. The first row of information for each station is the location-ellipse importance value, and the second is the depth-importance value. If the minimum is 100 and the average and maximum are both zero, the station was not used for location and, hence, not used in the importance section.

PART II

CODE DOCUMENTATION

V. STRUCTURE OF THE PROGRAM

In Part I, the analytical structure of the SNAP/D computer model was presented. Part II details the *program* modules, which are simply groups of subroutines. The *conceptual* modules in Part I were written using all capital letters. In Part II, conceptual modules are indicated by capital italics, whereas subroutine names are in capital letters.

INPUT STRUCTURE

Entry and exit from the SNAP/D software system occurs in the "root" program module SNAPD. That routine provides initialization of the computational environment and selection from the main menu.

Five major routines called from SNAPD are: (1) CALC, which interfaces with the set of calculative routines beginning with MAINX; (2) CTLDF, which provides menu selection support for control inputs; (3) DETDF, which provides menu selection and data base I/O support for detection inputs; (4) SIGDF, which provides menu selection and data base I/O support for all wave-related inputs; (5) TOPODF, which provides menu selection and data base I/O support for all topographic inputs.

In support of data base I/O are routines ISEL, IOPEN, and ICLOS. CTLDF, DETDF, SIGDF, and TOPODF call on "worker" routines to provide interactive dialogue, data base initialization, and data base organization, so that the data are acceptable to the calculative routines. CTLDF calls on CTLPDU, and DETDF calls on DETDU. SIGDF calls on WAVDU for nonspecific wave input, and on PWADU, PGWDU, LGWDU, SWDU, PPWDU, and RAWDU for wave inputs specific to P, Pg, Lg, S, pP, and Rayleigh waves, respectively. TOPODF calls on STADU, EPGDU, ESCDU, REGDU, and IMMDU for information specific to station data, epicenter grid data, epicenter/station calibration data, regional grid data, and importance-matrix data, respectively.

MATDU supports interactive dialogue pertaining to stable and tectonic media information, and TTIDU and TTSDU support interactive dialogue for travel-time data and travel-time standard deviations for routine, consists of INPUTC calling for a one-character input (used and INPDLO provide a common facility for entering latitude and longitude information for the topographic work routines.

Terminal input support, which requires interfacing with the LOGGER routines, consists of INPUTC calling for a one-character input (used mostly for terminal and terminal operator synchronization); INPUTD calling for a one-character input while prompting a default character; INPUTF calling for a file-name input; INPUTN calling for a numeric-string input; and INPUTS calling for a character-string input. Routine INPUTN calls on CHECKN for the numeric-string validation. A SNAP/D interactive section calls on STRF for a variety of character-string manipulation functions.

INTERNAL CODE STRUCTURE

Table 2 lists the conceptual modules and the particular subroutines used in implementing them. *TRANS* is performed by many subroutines, most with a specific algebraic function. Subroutine TRANS is the main driver for breaking the detection criterion into its subcriteria. TRANS converts the input detection criteria into a form that can be evaluated. It calls RULES, which directs the relevant algebraic manipulative routines, including SYNTAX, which checks for syntax errors in the subcriteria string; CHECK, which determines if the string is valid; and WRITE, which writes the string to the terminal. POUT, also called by RULES, writes out intermediate forms of the criterion string.

The functions of *EGRID*, *BINMB*, and *WAMP* are contained entirely in MAINX. *SPROB* is performed by MAINX with the probability function being calculated in subroutine PROBF. *GEOM* is performed by BNDRY and IFIND. BNDRY calculates the angular distances and azimuths between epicenter and stations. It also finds the distance traveled in each regional grid and calls IFIND. IFIND determines the corresponding regional grid index for each section of the epicenter/station path.

Table 2

CORRESPONDENCE OF MODULES WITH SUBROUTINES

Module	Subroutine Name	
TRANS	TRANS	RULES
	ADD	ALTOPO
	ASSOC	CHECK
	COMMUT	DISASS
	DISTRB	NEGOUT
	POTOAL	POUT
	PROBAB	REPLOP
	SPROB	SUBS
	SVBSET	SYNTAX
	WRITE	
EGRID	MAINX	
BINMB	MAINX	
WAMP	MAINX	
SPROB	MAINX	
	PROBF	
GEOM	BNDRY	
	IFIND	
NPROB	NUMBER	QPROB
	NETPRB	PROBK
	PRBCON	
ATSD	ATSD	
SUBSET	SUBSET	
PRINT	MAINX	
	PREPRT	
LOCATE[a]		

[a]Described by Systems, Science and Software.

The rest of the subroutines are algebraic. ALTOPO converts from algebraic form to reverse polish, whereas POTOAL converts from reverse polish to algebraic. ASSOC performs the associative law; DISASS does the opposite. COMMUT commutes elements of relevant operators such as addition. DISTRB changes an event description of the form $(A \cup B) \cap C$ to the form $(A \cap C) \cup (B \cap C)$. ADD performs the addition operator,

whereas NEGOUT replaces negation with subtraction. PROBAB passes the probability operator through the criterion, whereas SPROB passes the probability operator through individual wave combinations to obtain the probabilities needed by the *NPROB* module. REPLOP replaces algebraic operators with logical operators. Finally, SUBS finds and eliminates subsets within a wave combination, and SVBSET finds and eliminates subsets within subcriteria.

Module *NPROB* compromises five subroutines. NUMBER takes the output detection criterion from *TRANS*, accepts probabilities from *SPROB*, and performs the network detection calculations via the function QPROB. QPROB then takes the modified *SPROB* output and calls appropriate routines based on the number of dependencies. If there is one dependency, QPROB calls NETPRB [Wirth, 1977], which finds the probability of detection using the function PROBK. PROBK determines the probability of finding an exact number of events from two groups. If there are two dependencies, QPROB takes the modified *SPROB* output and readies it for the 2D convolution. That convolution is performed by PRBCON, which returns a final value to QPROB, yielding the detection probability for the given *TRANS* output.

The *ATSD* module is wholly performed in subroutine ATSD. Module *SUBSET* is performed by subroutine SUBSET, with the conditional probability calculated by NETPRB and PROBK.

The *PRINT* module is performed by both MAINX and PREPRT. PREPRT writes out the run mode, station tables, and desired wave tables. MAINX prints the summary network results, and, if desired, the detailed epicenter information.

The *LOCATE* module consists of routines supplied by Systems, Science and Software, which are described in the Appendix. *LOCATE* indicates certain errors, such as a value being outside table bounds. The module is fed information from LOCLOD, which uses the output from *ATSD*, *SPROB*, relevant input parameters, and in the case of a deep event, *SUBSET*.

VI. INTERACTIVE AND BATCH INPUTS

GENERAL COMMENTS

The SNAP/D software system was designed for interactive usage, with batch processing as a special case. Batch input consists of a stream of terminal commands, stored as a sequential file and directed at the SNAP/D terminal input logical unit (LUN). Further discussion of these input follows in the "Terminal I/O" subsection.

Batch usage differs from interactive usage in both LUN assignment and handling of pause commands. The following lists show how the LUN assignments differ:

Interactive LUNs	Batch LUNs
1. Log file (output)	1. Log print file
2. Data base input/output	2. Data base input/output
3. Printer file (output)	3. Printer file (output)
4. Terminal input	4. Pseudo-terminal input
5. Terminal output	5. Log print file

Pause commands are ignored under batch usage. The batch execution halts when an end-of-file condition is detected in the pseudo-terminal input.

A *numeric string* is defined as:

sign:digit1(s):decimal-point:digit1(s):E or D:sign:digit2(s) ,

where the count of digit1(s), the precision, may not exceed 15 digits; and the count of digit2(s), the exponent, may not exceed 2 digits. Some correct examples of numeric strings with similar values are

- 123456789, +123456789, 1.23456789E+8
- -6E5, -600000, -6+5
- 6D-5, 0.000006, 6-5

Incorrect numeric strings are as follows:

- 1234567890123456 (precision is too large).
- ++5 (multiple signs).
- 6D555 (exponent is too large).
- -E+2 (no fraction part).
- 5E (partial exponent part).
- 6x5 (unrecognized character x).

A numeric string can be entered "format-free" as long as the string is contained within the first 20 columns. The numeric string is terminated by the twenty-first column, or the first space after the start of the numeric string.

A *file name* has two parts: (1) a name consisting of eight or fewer alphanumeric characters followed by a period; (2) an extension of three or fewer alphanumeric characters. Both the name and extension must begin with an alphabetic character. Table 3 presents a list of extension names suggested for standardized use. For example, in a particular seismic study, a file associated with that study might have a file name of STUDY025.X1. As can be seen from Table 3, this would indicate P-wave data that comes from an explosion, within the aggregate of information associated with the particular study STUDY025.

TERMINAL I/O

All terminal inputs are preceded by informational messages and prompts that provide entry cues, such as a name (SIGMA 004), a range (0 - 1), or a default value. The type of reply is indicated by the number of trailing periods on the prompt:

Number of Periods	Requested Terminal Input
2	One-character input
3	Numeric-string input
4	Alphanumeric-string input

Default values are selected by typing the carriage return (CR) key.

Table 3

FILE-NAME EXTENSIONS

Extension[a]	File Contents
	Data Files
DET	Detection input data
STA	Station data
ESC	Epicenter/station calibration data
EPG	Epicenter grid data
REG	Regional grid data
IMM	Importance-matrix data
WAV	Case study wave file list
	Seismic Wave Data Files
Xk	Wave data used for an explosion
SQk	Wave data used for a shallow earthquake
DQk	Wave data used for a deep earthquake
ASk	Stable media attenuation data
ATk	Tectonic media attenuation data
TSk	Travel-time data for a shallow event
TDk	Travel-time data for a deep event
SSk	Travel-time standard deviation for a shallow event
SDk	Travel-time standard deviation for a deep event

[a]The variable k denotes a wave type as follows:

k	Wave
1	P
2	Pg
3	Lg
4	S
5	pP
6	Rayleigh

For a two- or three-period prompt, typing the "x" key will either terminate a "logical" group of questions, or exit a routine to a menu. Note that typing the "x" key after a four-period prompt will have no effect other than entering the character string "x," and that typing a finite sequence of "x" causes SNAPD to exit to the monitor level of commands.

Three other special keys may be used with a two- or three-period prompt:

1. ; comments, which provide documentation (of terminal input) to the LOGGER.
2. L, which activates the LOGGER.
3. O, which deactivates the LOGGER.

These three commands allow elementary editing capabilities in preparation of pseudo-terminal inputs for batch usage. However, an on-site editor will be required to produce acceptable batch inputs such as inserting Calculate commands, changing detection criteria, and appending several LOGGER productions into one batch input file.

The interactive commands used to enter and exit the main and submenus are shown in Fig. 3.

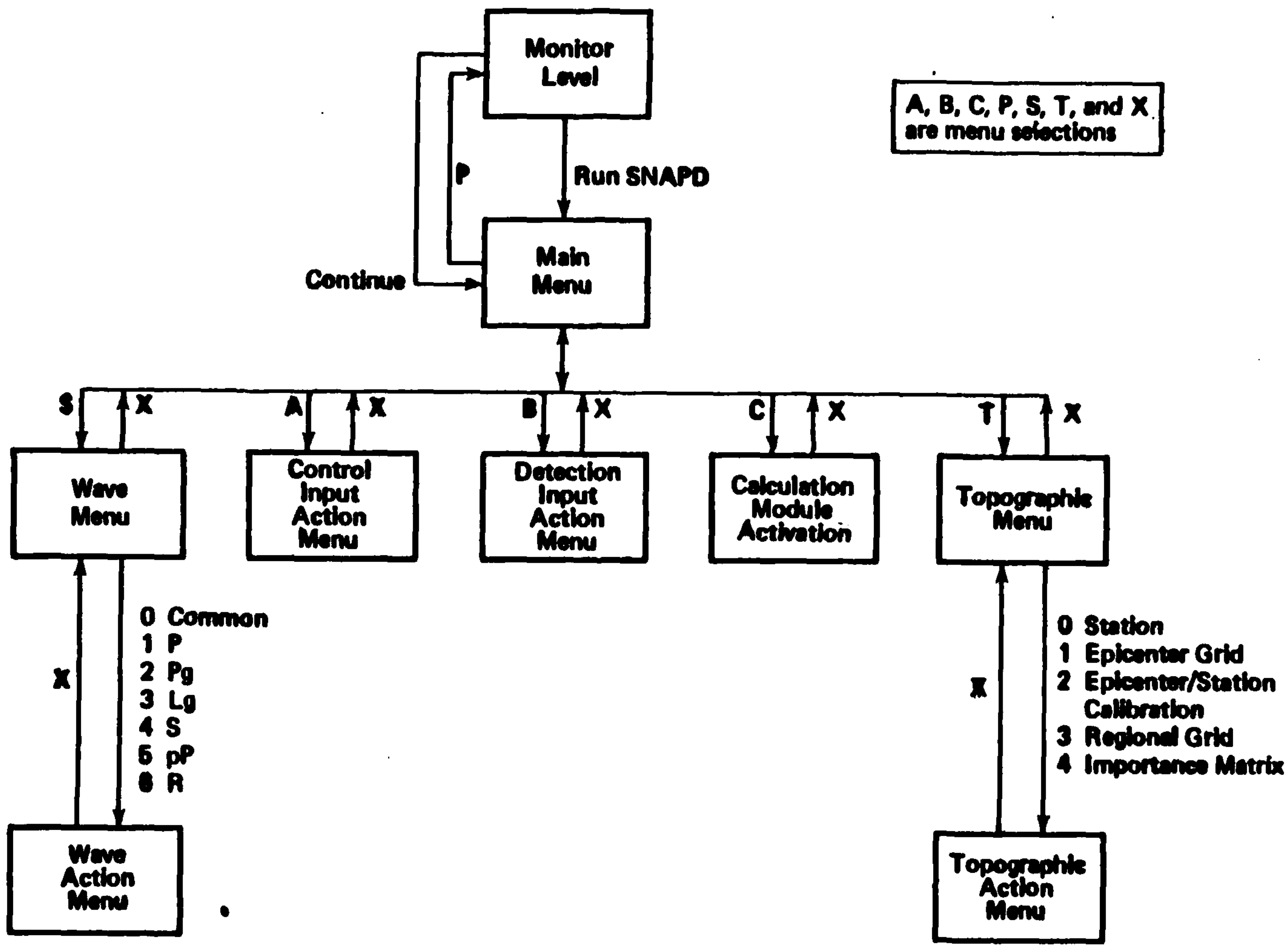

Fig. 3--Menu structure

VII. ERRORS AND DEFAULTS

Default values are always displayed, and can be selected by striking the CR key.

Four types of errors are detectable by SNAPD.

1. Value error, e.g., a negative probability.
2. Syntax error, e.g., a "7 × 7" numeric string.
3. Input error indicated by a nonzero status code.
4. I/O format errors from reading incorrect file types.

These error messages always refer to the last terminal input.

Some errors are inherently undetectable, such as uninitialized wave data. The user must take great care to avoid them.

Other areas where the user must exercise caution are as follows:

1. The regional grid must be designed to break at ±180 deg longitude and be indexed starting from the lower left-hand corner.
2. The lowest index in a row must be on the left-hand border.
3. The maximum number of magnitude corrections, ε_{ijk}, is limited to 100.
4. For the master-event and S-P calibration sets, Ω_j and ψ_j, the user can have up to 15 station indices per epicenter.
5. Importance sets for a location are limited to a maximum of six.

VIII. SAMPLE RUN

This section presents an abridged printout of a typical interactive session for a SNAPD run. For the sake of brevity, it was necessary to omit certain portions of the input and output printouts. Those portions of the printout omitted from the interactive input session are typically attenuation, travel-time, and travel-time standard-deviation table entries beyond the first three table entries, and station inputs for all but the first three stations. Detailed epicenter output is shown for only the first three epicenters.

AC90C114

Interactive Input Session

```
SNAP/D 0.0

  SEISMIC ANALYST TOOL

  GENERAL COMMAND MENU

  A.CNTL INPUT  B.DET INPUT    C.CALCULATE    D.DISPLAY
  E..           F..            G..            H.HELP
  I.INITIALIZE  J..            K..            L.LOG ENABLE
  M.MENU        N.RESERVEC     O.LOG DISABLE  P.PAUSE
  Q.WHERE       R.READ         S.WAVE INPUT   T.TOPO INPUT
  U.UPDATE      V..            W.WRITE        X.EXIT
  Y.RESERVED    Z.RESET        ;.LOG COMMENT

  SELECT ITEM  .. Q ..
 A
```


PRECEDING PAGE BLANK-NOT FIL

```
SNAP/D(CTLOF)

 CONTROL INPUTS

 A..            B..            C..            D.DISPLAY
 E..            F..            G..            H.HELP
 I.INITIALIZE   J..            K..            L.LOG ENABLE
 M.MENU         N.RESERVED     O.LOG DISABLE  P.PAUSE
 Q.WHERE        R..            S..            T..
 U.UPDATE       V..            W..            X.EXIT
 Y.RESERVED     Z.RESET        ;.LOG COMMENT

 SELECT ITEM  .. Q ..
U
 CALCULATION MODE: 1-DETECTION 2-LOCATION 3-BOTH .. 2 ..
3
 EVENT TYPE: 1-EXPLOSION 2-SHALLOW QUAKE 3-DEEP QUAKE .. 2 ..
1
 OUTPUT CONTOUR TYPE: 1-MAGNITUDE 2-PROBABILITY .. 1 ..

USE OF IMPORTANCE MATRIX: 1-Y 2-N .. 2 ..
1
 SNAP/D(CTLOF) CONTROL INPUTS
 SELECT ITEM  .. Q ..
X
 SNAP/D(MAIN)
 SELECT ITEM  .. Q ..
B
```

```
SNAP/C(DETDF)

  DETECTION INPUTS

  A..             B..             C..             D.DISPLAY
  E..             F..             G..             H.HELP
  I.INITIALIZE    J..             K..             L.LOG ENABLE
  M.MENU          N.RESERVED      O.LOG DISABLE   P.PAUSE
  Q.WHERE         R.READ          S..             T..
  U.UPDATE        V..             W.WRITE         X.EXIT
  Y.RESERVED      Z.RESET         ;.LOG COMMENT

  SELECT ITEM  .. Q ..
 R
  FILE NAME .... NONE         ....
 TSTCSE.DET
  TSTCSE.DET  : DETECTION FILE (TSTCSE.DET)
  SELECT ITEM  .. Q ..
 U
```

```
DETECTION INPUT FILE NAME: TSTCSE.DET
  FILE DESCRIPTION .... DETECTION FILE (TSTCSE.DET)
  ....

 DETECTION CRITERIA ....
  ((P+PG)*LG)/4+P/4                               ....

 FOR MAGNITUDE CONTOURS, INPUT:
  PT   (PROBABILITY THRESHOLD) ... 0.900000     ...

 MMIN (LO RANGE OF MAGNITUDE) ...  3.00000     ...

 MMAX (HI RANGE OF MAGNITUDE) ...  6.00000     ...

 FOR PROBABILITY CONTOURS, INPUT:
  MT   (MAGNITUDE THRESHOLD)   ...  4.00000     ...

 SNAP/D(DETDF) DETECTION INPUTS
  SELECT ITEM  .. Q ..
 X
  SNAP/D(MAIN)
  SELECT ITEM  .. Q ..
 $
```

```
SNAP/D(SIGDF)

  WAVE INPUTS

      0-COMMON WAVE DATABASE
      1-P  WAVE DATABASE
      2-PG WAVE DATABASE
      3-LG WAVE DATABASE
      4-S  WAVE DATABASE
      5-PP WAVE DATABASE
      6-R  WAVE DATABASE
      X-EXIT TO MAIN MENU

  SELECT ITEM  .. 0 ..


  A..             B..             C..             D.DISPLAY
  E..             F..             G..             H.HELP
  I.INITIALIZE    J..             K..             L.LOG ENABLE
  M.MENU          N.RESERVED      O.LOG DISABLE   P.PAUSE
  Q.WHERE         R.READ          S..             T..
  U.UPDATE        V..             W.WRITE         X.EXIT
  Y.RESERVED      Z.RESET         ;.LOG COMMENT

  SELECT ITEM  .. Q ..
 R
  FILE NAME .... NONE         ....
 TSTCSE.WAV
  TSTCSE.WAV  : WAVE INPUTS (TSTCSE.WAV)
  SELECT ITEM  .. Q ..
 D
```

```
COMMON WAVE FILE NAME: TSTCSE.WAV
  FILE DESCRIPTION .... WAVE INPUTS (TSTCSE.WAV)
  ....

 ** NOTE: ZERO IS CHOSEN FOR THE FOLLOWING VALUE(MBL)
          ONLY FOR DETECTION AND LOCATION MODE, AND THEN
          LOCATION CALCULATIONS ARE PERFORMED FOR DETECTION
          THRESHOLDS AT EACH EPICENTER.
  MBL(LOCATION MB VALUE) ... 0.          ...

 PC(CONFIDENCE PCT,0-100) ...  90.0000     ...

 LIST WAVES EXCLUDED FROM LOCATION CALCULATIONS:
  EXCLUDED WAVE NO.(0-6) ...  0 ...

 EXCLUDED WAVE NO.(0-6) ...  0 ...

 EXCLUDED WAVE NO.(0-6) ...  0 ...

 EXCLUDED WAVE NO.(0-6) ...  0 ...

 EXCLUDED WAVE NO.(0-6) ...  0 ...

 EXCLUDED WAVE NO.(0-6) ...  0 ...

 EXCLUDED WAVE NO.(0-6) ...  0 ...

 EXCLUDED WAVE NO.(0-6) ...  0 ...

 EXCLUDED WAVE NO.(0-6) ...  0 ...

 EXCLUDED WAVE NO.(0-6) ...  0 ...

 LIST WAVE FILES USED FOR DETECTION AND LOCATION:
  P  WAVE FILE NAME .... TSTCSE.X1     ....
  PG WAVE FILE NAME .... TSTCSE.X2     ....
  LG WAVE FILE NAME .... TSTCSE.X3     ....
  S  WAVE FILE NAME .... TSTCSE.X4     ....
  PP WAVE FILE NAME .... NONE          ....
  R  WAVE FILE NAME .... TSTCSE.X6     ....
  SNAP/D(SIGDF) COMMON WAVE DATA
  SELECT ITEM  .. Q ..
 X
```

```
SNAP/D(SIGDF)

 WAVE INPUTS

     0-COMMON WAVE DATABASE
     1-P  WAVE DATABASE
     2-PG WAVE DATABASE
     3-LG WAVE DATABASE
     4-S  WAVE DATABASE
     5-PP WAVE DATABASE
     6-R  WAVE DATABASE
     X-EXIT TO MAIN MENU

 SELECT ITEM  .. 0 ..
1

 A..             B..             C..             D.DISPLAY
 E..             F..             G..             H.HELP
 I-INITIALIZE    J..             K..             L.LOG ENABLE
 M.MENU          N.RESERVED      O.LOG DISABLE   P.PAUSE
 Q.WHERE         R.READ          S..             T..
 U.UPDATE        V..             W.WRITE         X.EXIT
 Y.RESERVED      Z.RESET         ;.LOG COMMENT

 SELECT ITEM  .. Q ..
R
 P WAVE FILE SET SELECTOR

     0-WAVE FILE
     1-STABLE MEDIA ATTENUATION FILE
     2-TECTONIC MEDIA ATTENUATION FILE
     3-TRAVEL TIPE FILE
     4-TRAVEL TIME S.D. FILE

 SELECT ITEM  .. 0 ..

** NOTE: P-WAVE FILE NAME SHOULD INDICATE X FOR
         EXPLOSION, SQ FOR SHALLOW QUAKE OR DQ FOR
         DEEP QUAKE, E.G.
         FILENAME.X1, FILENAME.SQ1, FILENAME.DQ1
 FILE NAME .... TSTCSE.X1    ....

TSTCSE.X1   : P WAVE FILE TEST (TSTCSE.X1)
 SELECT ITEM  .. Q ..
R
 P WAVE FILE SET SELECTOR

     0-WAVE FILE
     1-STABLE MEDIA ATTENUATION FILE
     2-TECTONIC PEDIA ATTENUATION FILE
     3-TRAVEL TIME FILE
     4-TRAVEL TIME S.D. FILE

 SELECT ITEM  .. 0 ..
1
 ** NOTE: P-WAVE STABLE MEDIA ATTENUATION TABLE
         FILE NAME SHOULD INDICATE S FOR SHALLOW EVENT OR
         D FOR DEEP QUAKE, E.G.
         FILENAME.S1, FILENAME.D1
         SHALLOW ATTENTUATION TABLE STARTS WITH PN-WAVE
 FILE NAME .... TSTCSE.AS1   ....
```

```
 SELECT ITEM  .. Q ..
R
 P WAVE FILE SET SELECTOR

     0-WAVE FILE
     1-STABLE MEDIA ATTENUATION FILE
     2-TECTONIC MEDIA ATTENUATION FILE
     3-TRAVEL TIME FILE
     4-TRAVEL TIME S.D. FILE

 SELECT ITEM  .. 0 ..
2
 FILE NAME .... TSTCSE.AT1   ....

TSTCSE.AT1  : P-WAVE TECT. ATTEN. TABLE (TSTCSE.AT1)
 SELECT ITEM  .. Q ..
R
 P WAVE FILE SET SELECTOR

     0-WAVE FILE
     1-STABLE MEDIA ATTENUATION FILE
     2-TECTONIC MEDIA ATTENUATION FILE
     3-TRAVEL TIME FILE
     4-TRAVEL TIME S.D. FILE

 SELECT ITEM  .. 0 ..
3
 ** NOTE: P-WAVE TRAVEL TIME TABLE FILE NAME SHOULD
          INDICATE S FOR SHALLOW QUAKE OR D FOR DEEP QUAKE, E.G.
          FILENAME.TS1, FILENAME.TD1
 FILE NAME .... TSTCSE.TS1   ....

TSTCSE.TS1  : P-WAVE SHALLOW TRAVEL-TIME (TSTCSE.TS1)
 SELECT ITEM  .. Q ..
R
 P WAVE FILE SET SELECTOR

     0-WAVE FILE
     1-STABLE MEDIA ATTENUATION FILE
     2-TECTONIC MEDIA ATTENUATION FILE
     3-TRAVEL TIME FILE
     4-TRAVEL TIME S.D. FILE

 SELECT ITEM  .. 0 ..
4
 FILE NAME .... TSTCSE.SS1   ....

TSTCSE.SS1  : P-WAVE STANDARD DEVIATIONS (TSTCSE.SS1)
 SELECT ITEM  .. Q ..
D
```

```
P WAVE FILE NAME: TSTCSE.X1
  FILE DESCRIPTION .... P WAVE FILE TEST (TSTCSE.X1)
  ....

 STABLE MEDIA ATTENUATION TABLE FILE NAME: TSTCSE.AS1
  FILE DESCRIPTION .... P-WAVE STABLE ATTEN. TABLE (TSTCSE.AS1)
  ....

 ITEM-  1 ARC DISTANCE (DEG) O.            B-FACTOR O.
  C-FACTOR O.            CHANGE ? (Y-N OR X)
  SELECT ITEM  .. N ..

 ITEM-  2 ARC DISTANCE (DEG)  1.00000     B-FACTOR O.
  C-FACTOR O.            CHANGE ? (Y-N OR X)
  SELECT ITEM  .. N ..

 ITEM-  3 ARC DISTANCE (DEG)  2.00000     B-FACTOR -2.20000
  C-FACTOR O.            CHANGE ? (Y-N OR X)
  SELECT ITEM  .. N ..
 X
  TECTONIC MEDIA ATTENUATION TABLE FILE NAME: TSTCSE.AT1
  FILE DESCRIPTION .... P-WAVE TECT. ATTEN. TABLE (TSTCSE.AT1)
  ....

 ITEM-  1 ARC DISTANCE (DEG) O.            B-FACTOR  2.20000
  C-FACTOR O.            CHANGE ? (Y-N OR X)
  SELECT ITEM  .. N ..

 ITEM-  2 ARC DISTANCE (DEG)  1.00000     B-FACTOR  2.20000
  C-FACTOR O.            CHANGE ? (Y-N OR X)
  SELECT ITEM  .. N ..

 ITEM-  3 ARC DISTANCE (DEG)  2.00000     B-FACTOR  2.50000
  C-FACTOR O.            CHANGE ? (Y-N OR X)
  SELECT ITEM  .. N ..
 X
  TRAVEL-TIME TABLE FILE NAME: TSTCSE.TS1
  FILE DESCRIPTION .... P-WAVE SHALLOW TRAVEL-TIME (TSTCSE.TS1)
  ....

 ITEM-  1 ARC DISTANCE (DEG) O.
    TRAVEL-TIME (SEC) O.           CHANGE? (Y-N OR X)
  SELECT ITEM  .. N ..

 ITEM-  2 ARC DISTANCE (DEG)  1.00000
    TRAVEL-TIME (SEC)  21.1400     CHANGE? (Y-N OR X)
  SELECT ITEM  .. N ..

 ITEM-  3 ARC DISTANCE (DEG)  2.00000
    TRAVEL-TIME (SEC)  34.8600     CHANGE? (Y-N OR X)
  SELECT ITEM  .. N ..
 X
  TRAVEL-TIME S.D. TABLE FILE NAME: TSTCSE.SS1
  FILE DESCRIPTION .... P-WAVE STANDARD DEVIATIONS (TSTCSE.SS1)
  ....

 ITEM-  1 ARC DISTANCE (DEG) O.
    TRAVEL-TIME S.D. (SEC) O.           CHANGE? (Y-N OR X)
  SELECT ITEM  .. N ..

 ITEM-  2 ARC DISTANCE (DEG)  1.00000
    TRAVEL-TIME S.D. (SEC) 0.800000     CHANGE? (Y-N OR X)
  SELECT ITEM  .. N
```

```
ITEM-  3 ARC DISTANCE (DEG)  2.00000
   TRAVEL-TIME S.D. (SEC)  1.30000     CHANGE? (Y-N OR X)
 SELECT ITEM  .. N ..
X
 SIGMA OD1(P -WAVE READING ERROR/SEC) ... 0.750000     ...

VP(P -WAVE SPEED,KM/SEC) ...  6.00000     ...

SNAP/D(SIGDF) P WAVE DATA
 SELECT ITEM  .. Q ..
X
```

```
SNAP/D(SIGDF)

  WAVE INPUTS

      0-COMMON WAVE DATABASE
      1-P  WAVE DATABASE
      2-PG WAVE DATABASE
      3-LG WAVE DATABASE
      4-S  WAVE DATABASE
      5-PP WAVE DATABASE
      6-R  WAVE DATABASE
      X-EXIT TO MAIN MENU

  SELECT ITEM  .. 1 ..
 2

  A..            B..            C..            D.DISPLAY
  E..            F..            G..            H.HELP
  I.INITIALIZE   J..            K..            L.LOG ENABLE
  M.MENU         N.RESERVED     O.LOG DISABLE  P.PAUSE
  Q.WHERE        R.READ         S..            T..
  U.UPDATE       V..            W.WRITE        X.EXIT
  Y.RESERVED     Z.RESET        ;.LOG COMMENT

  SELECT ITEM  .. Q ..
 R
  PG WAVE FILE SET SELECTOR

      0-WAVE FILE
      1-STABLE MEDIA ATTENUATION FILE
      2-TECTONIC MEDIA ATTENUATION FILE
      3-TRAVEL TIME FILE
      4-TRAVEL TIME S.D. FILE

  SELECT ITEM  .. 0 ..

 FILE NAME .... TSTCSE.X2    ....

 TSTCSE.X2   : PG WAVE FILE INPUTS (TSTCSE.X2)
  SELECT ITEM  .. Q ..
 R
  PG WAVE FILE SET SELECTOR

      0-WAVE FILE
      1-STABLE MEDIA ATTENUATION FILE
      2-TECTONIC MEDIA ATTENUATION FILE
      3-TRAVEL TIME FILE
      4-TRAVEL TIME S.D. FILE

  SELECT ITEM  .. 0 ..
 1
  FILE NAME .... TSTCSE.AS2   ....

 TSTCSE.AS2  : PG STABLE ATTENUATION TABLE (TSTCSE.AS2)
  SELECT ITEM  .. Q ..
 R
  PG WAVE FILE SET SELECTOR

      0-WAVE FILE
      1-STABLE MEDIA ATTENUATION FILE
      2-TECTONIC MEDIA ATTENUATION FILE
      3-TRAVEL TIME FILE
      4-TRAVEL TIME S.D. FILE
```

```
 SELECT ITEM  .. 0 ..
2
 FILE NAME .... TSTCSE.AT2   ....

TSTCSE.AT2  : PG TECTONIC ATTEN. TABLE (TSTCSE.AT2)
 SELECT ITEM  .. Q ..
R
 PG WAVE FILE SET SELECTOR

     0-WAVE FILE
     1-STABLE MEDIA ATTENUATION FILE
     2-TECTONIC MEDIA ATTENUATION FILE
     3-TRAVEL TIME FILE
     4-TRAVEL TIME S.D. FILE

 SELECT ITEM  .. 0 ..
3
 FILE NAME .... TSTCSE,TS2   ....

TSTCSE.TS2  : PG TRAVEL-TIME TABLE (TSTCSE.TS2)
 SELECT ITEM  .. Q ..
R
 PG WAVE FILE SET SELECTOR

     0-WAVE FILE
     1-STABLE MEDIA ATTENUATION FILE
     2-TECTONIC MEDIA ATTENUATION FILE
     3-TRAVEL TIPE FILE
     4-TRAVEL TIME S.D. FILE

 SELECT ITEM  .. 0 ..
4
 FILE NAPE .... TSTCSE.SS2   ....

TSTCSE.SS2  : PG TRAVEL-TIME STAND. DEVS. (TSTCSE.SS2)
 SELECT ITEM  .. Q ..
D
```

```
PG WAVE FILE NAME: TSTCSE.X2
 FILE DESCRIPTION ..... PG WAVE FILE INPUTS (TSTCSE.X2)
 ....

STABLE MEDIA ATTENUATION TABLE FILE NAME: TSTCSE.AS2
 FILE DESCRIPTION ..... PG STABLE ATTENUATION TABLE (TSTCSE.AS2)
 ....

ITEM-  1 ARC DISTANCE (DEG) 0.100000     B-FACTOR  3.72000
 C-FACTOR 0.            CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  2 ARC DISTANCE (DEG) 0.200000     B-FACTOR  2.67000
 C-FACTOR 0.            CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  3 ARC DISTANCE (DEG) 0.500000     B-FACTOR  1.27000
 C-FACTOR 0.            CHANGE ? (Y-N OR X).
 SELECT ITEM  .. N ..
X
 TECTONIC MEDIA ATTENUATION TABLE FILE NAME: TSTCSE.AT2
 FILE DESCRIPTION ..... PG TECTONIC ATTEN. TABLE (TSTCSE.AT2)
 ....

ITEM-  1 ARC DISTANCE (DEG) 0.100000     B-FACTOR  3.72000
 C-FACTOR 0.            CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  2 ARC DISTANCE (DEG) 0.200000     B-FACTOR  2.37000
 C-FACTOR 0.            CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  3 ARC DISTANCE (DEG) 0.500000     B-FACTOR 0.980000
 C-FACTOR 0.            CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..
X
 TRAVEL-TIME TABLE FILE NAME: TSTCSE.TS2
 FILE DESCRIPTION ..... PG TRAVEL-TIME TABLE (TSTCSE.TS2)
 ....

ITEM-  1 ARC DISTANCE (DEG) 0.
   TRAVEL-TIME (SEC) 0.           CHANGE? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  2 ARC DISTANCE (DEG)  1.00000
   TRAVEL-TIME (SEC)  18.5300     CHANGE? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  3 ARC DISTANCE (DEG)  2.00000
   TRAVEL-TIME (SEC)  37.0600     CHANGE? (Y-N OR X)
 SELECT ITEM  .. N ..
X
 TRAVEL-TIME S.D. TABLE FILE NAME: TSTCSE.SS2
 FILE DESCRIPTION ..... PG TRAVEL-TIME STAND. DEVS. (TSTCSE.SS2)
 ....

ITEM-  1 ARC DISTANCE (DEG) 0.
   TRAVEL-TIME S.D. (SEC) 0.           CHANGE? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  2 ARC DISTANCE (DEG)  1.00000
   TRAVEL-TIME S.D. (SEC) 0.500000     CHANGE? (Y-N OR X)
 SELECT ITEM  .. N ..
```

```
ITEM-  3 ARC DISTANCE (DEG)  2.00000
   TRAVEL-TIME S.D. (SEC)  1.00000     CHANGE? (Y-N OR X)
 SELECT ITEM  .. N ..
X
 KE SO2(PG-WAVE EVENT FACTOR,STABLE) ... 0.           ...

KE TO2(PG-WAVE EVENT FACTOR,TECT) ... 0.           ...

KM SO2(PG-WAVE MAG FACTOR,STABLE) ...  1.00000     ...

KM TO2(PG-WAVE MAG FACTOR,TECT) ...  1.00000     ...

SIGMA OO2(PG-WAVE READING ERROR,SEC) ... 0.750000     ...

SNAP/D(SIGDF) PG WAVE DATA
 SELECT ITEM  .. Q ..
X
```

```
SNAP/D(SIGDF)

 WAVE INPUTS

     0-COMMON WAVE DATABASE
     1-P  WAVE DATABASE
     2-PG WAVE DATABASE
     3-LG WAVE DATABASE
     4-S  WAVE DATABASE
     5-PP WAVE DATABASE
     6-R  WAVE DATABASE
     X-EXIT TO MAIN MENU

 SELECT ITEM  .. 2 ..
3

 A..            B..            C..            D.DISPLAY
 E..            F..            G..            H.HELP
 I.INITIALIZE   J..            K..            L.LOG ENABLE
 M.MENU         N.RESERVED     O.LOG DISABLE  P.PAUSE
 Q.WHERE        R.READ         S..            T..
 U.UPDATE       V..            W.WRITE        X.EXIT
 Y.RESERVED     Z.RESET        /.LOG COMMENT

 SELECT ITEM  .. Q ..
R
 LG WAVE FILE SET SELECTOR

     0-WAVE FILE
     1-STABLE MEDIA ATTENUATION FILE
     2-TECTONIC MEDIA ATTENUATION FILE

 SELECT ITEM  .. 0 ..

** NOTE: LG-WAVE FILE NAME SHOULD INDICATE X FOR
         EXPLOSION OR SC FOR SHALLOW QUAKE, E.G.
         FILENAME.X3, FILENAME.SQ2
 FILE NAME .... TSTCSE.X3    ....

TSTCSE.X3   : LG WAVE FILE INPUTS (TSTCSE.X3)
 SELECT ITEM  .. Q ..
R
 LG WAVE FILE SET SELECTOR

     0-WAVE FILE
     1-STABLE MEDIA ATTENUATION FILE
     2-TECTONIC MEDIA ATTENUATION FILE

 SELECT ITEM  .. 0 ..
1
 FILE NAME .... TSTCSE.AS3   ....

TSTCSE.AS3  : LG STABLE ATTENUATION TABLE (TSTCSE.AS3)
 SELECT ITEM  .. Q ..
R
 LG WAVE FILE SET SELECTOR

     0-WAVE FILE
     1-STABLE MEDIA ATTENUATION FILE
     2-TECTONIC MEDIA ATTENUATION FILE
```

```
 FILE NAME .... TSTCSE.AT3   ....

TSTCSE.AT3  : LG TECTONIC ATTEN. TABLE (TSTCSE.AT3)
 SELECT ITEM  .. Q ..
D
```

```
LG WAVE FILE NAME: TSTCSE.X3
 FILE DESCRIPTION .... LG WAVE FILE INPUTS (TSTCSE.X3)
 ....

STABLE MEDIA ATTENUATION TABLE FILE NAME: TSTCSE.AS3
 FILE DESCRIPTION .... LG STABLE ATTENUATION TABLE (TSTCSE.AS3)
 ....

ITEM-  1 ARC DISTANCE (DEG) 0.100000     B-FACTOR  3.90000
 C-FACTOR 0.             CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  2 ARC DISTANCE (DEG) 0.200000     B-FACTOR  2.84000
 C-FACTOR 0.             CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  3 ARC DISTANCE (DEG) 0.500000     B-FACTOR  1.45000
 C-FACTOR 0.             CHANGE ? (Y-N OR X).
 SELECT ITEM  .. N ..
X
 TECTONIC MEDIA ATTENUATION TABLE FILE NAME: TSTCSE.AT3
 FILE DESCRIPTION .... LG TECTONIC ATTEN. TABLE (TSTCSE.AT3)
 ....

ITEM-  1 ARC DISTANCE (DEG) 0.100000     B-FACTOR  3.90000
 C-FACTOR 0.             CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  2 ARC DISTANCE (DEG) 0.200000     B-FACTOR  2.55000
 C-FACTOR 0.             CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  3 ARC DISTANCE (DEG) 0.500000     B-FACTOR 0.760000
 C-FACTOR 0.             CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..
X
 KE SO3(LG-WAVE EVENT FACTOR,STABLE) ... -.500000     ...

KE TO3(LG-WAVE EVENT FACTOR,TECT) ... -.500000     ...

KM SO3(LG-WAVE MAG FACTOR,STABLE) ...  1.00000     ...

KM TO3(LG-WAVE MAG FACTOR,TECT) ...  1.00000     ...

SNAP/D(SIGDF) LG WAVE DATA
 SELECT ITEM  .. Q ..
X
```

```
  ...... WAVE DATABASE
  .   WAVE DA..BASE
  ..  WAVE DATABASE
   .  WAVE DATABASE
  . . WAVE DATABASE
  . .. WAVE DATABASE
  . .  WAVE DATABASE
  . EXIT TO MAIN MENU

 ..... ITEM  .. 3 ..

.                B..             C..             D.DISPLAY
.                F..             G..             H.HELP
. INITIALIZE     J..             K..             L.LOG ENABLE
..MENU           N.RESERVED      O.LOG DISABLE   P.PAUSE
. WHERE          R.READ          S..             T..
..UPDATE         V..             W.WRITE         X.EXIT
..RESERVED       Z.RESET         ;.LOG COMMENT

SELECT ITEM  .. Q ..
R
S WAVE FILE SET SELECTOR

    O-WAVE FILE
    1-STABLE MEDIA ATTENUATION FILE
    2-TECTONIC MEDIA ATTENUATION FILE

SELECT ITEM  .. 0 ..

** NOTE: S-WAVE FILE NAME SHOULD INDICATE X FOR
         EXPLOSION, SQ FOR SHALLOW QUAKE OR DQ FOR DEEP QUAKE,
         E.G. FILENAME.X4, FILENAME.SQ4, FILENAME.DQ4
FILE NAME .... TSTCSE.X4     ....

TSTCSE.X4    : S WAVE FILE (TSTCSE.X4)
SELECT ITEM  .. Q ..
R
S WAVE FILE SET SELECTOR

    O-WAVE FILE
    1-STABLE MEDIA ATTENUATION FILE
    2-TECTONIC MEDIA ATTENUATION FILE

SELECT ITEM  .. 0 ..
1
** NOTE: S-WAVE STABLE MEDIA ATTENUATION TABLE FILE
         NAME SHOULD INDICATE S FOR SHALLOW EVENT OR D FOR
```

```
    1-STABLE MEDIA ATTENUATION FILE
    2-TECTONIC MEDIA ATTENUATION FILE

 SELECT ITEM  .. 0 ..
2
 FILE NAME .... TSTCSE.AT4   ....

TSTCSE.AT4  : S-WAVE TECT. ATTEN. TABLE (TSTCSE.AT4)
 SELECT ITEM  .. 0 ..
0
```

```
S WAVE FILE NAME: TSTCSE.X4
 FILE DESCRIPTION .... S WAVE FILE (TSTCSE.X4)
 ....

STABLE MEDIA ATTENUATION TABLE FILE NAME: TSTCSE.AS4
 FILE DESCRIPTION .... S-WAVE STABLE ATTEN. TABLE (TSTCSE.AS4)
 ....

ITEM-  1 ARC DISTANCE (DEG) 0.100000     B-FACTOR  3.40000
 C-FACTOR 0.           CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  2 ARC DISTANCE (DEG) 0.200000     B-FACTOR  2.47000
 C-FACTOR 0.           CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  3 ARC DISTANCE (DEG) 0.500000     B-FACTOR  1.23000
 C-FACTOR 0.           CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..
X
 TECTONIC MEDIA ATTENUATION TABLE FILE NAME: TSTCSE.AT4
 FILE DESCRIPTION .... S-WAVE TECT. ATTEN. TABLE (TSTCSE.AT4)
 ....

ITEM-  1 ARC DISTANCE (DEG) 0.100000     B-FACTOR  3.40000
 C-FACTOR 0.           CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  2 ARC DISTANCE (DEG) 0.200000     B-FACTOR  2.19000
 C-FACTOR 0.           CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..

ITEM-  3 ARC DISTANCE (DEG) 0.500000     B-FACTOR 0.600000
 C-FACTOR 0.           CHANGE ? (Y-N OR X)
 SELECT ITEM  .. N ..
X
 KE S04(S -WAVE EVENT FACTOR,STABLE) ... -.500000    ...

KE T04(S -WAVE EVENT FACTOR,TECT) ... -.500000    ...

KM S04(S -WAVE MAG FACTOR,STABLE) ...  1.00000    ...

KM S04(S -WAVE MAG FACTOR,TECT) ...  1.00000    ...

SIGMA 004(S -WAVE READING ERROR,SEC) ...  1.00000    ...

VP/VS(SPEED RATIO FCR S-P CALIB) ...  1.71000    ...

SNAP/D(SIGDF) S WAVE DATA
 SELECT ITEM  .. Q ..
X
```

```
SNAP/D(SIGDF)

  WAVE INPUTS

      0-COMMON WAVE DATABASE
      1-P  WAVE DATABASE
      2-PG WAVE DATABASE
      3-LG WAVE DATABASE
      4-S  WAVE DATABASE
      5-PP WAVE DATABASE
      6-R  WAVE DATABASE
      X-EXIT TO MAIN MENU

 SELECT ITEM  .. 4 ..
X
 SNAP/D(MAIN)
 SELECT ITEM  .. Q ..
T
```

```
SNAP/D(TOPODF)

  TOPOGRAPHIC INPUTS

      0-STATION DATA
      1-EPICENTER GRID DATA
      2-EPICENTER/STATION CALIBRATION DATA
      3-REGIONAL GRID DATA
      4-IMPORTANCE MATRIX DATA
      X-EXIT TO MAIN MENU

  SELECT ITEM  .. 0 ..


  A..            B..            C..            D.DISPLAY
  E..            F..            G..            H.HELP
  I.INITIALIZE   J..            K..            L.LOG ENABLE
  M.MENU         N.RESERVED     O.LOG DISABLE  P.PAUSE
  Q.WHERE        R.READ         S..            T..
  U.UPDATE       V..            W.WRITE        X.EXIT
  Y.RESERVED     Z.RESET        ;.LOG COMMENT

  SELECT ITEM  .. Q ..
 R
  FILE NAME ..... NONE          ....
 TSTCSE.STA
  TSTCSE.STA  : 22 WORLDWIDE STATIONS (TSTCSE.STA)
  SELECT ITEM  .. G ..
 D
```

```
STATION FILE NAME: TSTCSE.STA
  FILE DESCRIPTION .... 22 WORLDWIDE STATIONS (TSTCSE.STA)
  ....
 NO. OF STATIONS ...  22 ...
```

```
MU N 1 (P -WAVE NOISE LEVEL) ...  5.00000     ...
 SIGMA N 1 (P -WAVE NOISE SD) ... 0.109000     ...
 SIGMA S 1 (P -WAVE SIG AMP SD/P MAG) ... 0.152000     ...
 R  1 (P -WAVE SNR) ...  2.00000     ...
```

```
MU N 2 (PG-WAVE NOISE LEVEL) ...  5.00000     ...
 SIGMA N 2 (PG-WAVE NOISE SD) ... 0.109000     ...
 SIGMA S 2 (PG-WAVE SIG AMP SD/PGMAG) ... 0.152000     ...
 SIGMA B 2 (PG-WAVE SIG AMP SD/MB) ... 0.600000     ...
 R  2 (PG-WAVE SNR) ...  2.00000     ...
```

```
MU N 3 (LG-WAVE NOISE LEVEL) ...  5.00000     ...
 SIGMA N 3 (LG-WAVE NOISE SD) ... 0.109000     ...
 SIGMA S 3 (LG-WAVE SIG AMP SD/LGMAG) ... 0.152000     ...
 SIGMA B 3 (LG-WAVE SIG AMP SD/MB) ... 0.600000     ...
 R  3 (LG-WAVE SNR) ...  2.00000     ...
```

```
MU N 4 (S -WAVE NOISE LEVEL) ...  5.00000     ...
 SIGMA N 4 (S -WAVE NOISE SD) ... 0.109000     ...
 SIGMA S 4 (S -WAVE SIG AMP SD/S MAG) ... 0.152000     ...
 SIGMA B 4 (S -WAVE SIG AMP SD/MB) ... 0.600000     ...
 R  4 (S -WAVE SNR) ...  2.00000     ...
```

```
MU N 5 (PP-WAVE NOISE LEVEL) ...  5.00000     ...
 SIGMA N 5 (PP-WAVE NOISE SD) ... 0.109000     ...
 SIGMA S 5 (PP-WAVE SIG AMP SD/PPMAG) ... 0.152000     ...
 SIGMA B 5 (PP-WAVE SIG AMP SD/MB) ... 0.600000     ...
 R  5 (PP-WAVE SNR) ...  2.00000    ....
```

```
MU N 6 (R -WAVE NOISE LEVEL) ...  10.0000     ...
 SIGMA N 6 (R -WAVE NOISE SD) ... 0.109000     ...
 SIGMA S 6 (R -WAVE SIG AMP SD/R MAG) ... 0.152000     ...
 SIGMA B 6 (R -WAVE SIG AMP SD/MB) ... 0.500000     ...
 R  6 (R -WAVE SNR) ...  2.00000     ...
```

```
FOR STATION SPECIFIC DATA ENTER STATION NO(1-75) OR X ...   1 ...

 STATION  1 NAME (4 CHARACTERS) .... ANMO ....

 THETA  1 (STATION  1 LATITUDE) ...  34.9417
  DEGREES LATITUDE (0-90)  ... 34.0 ...

 MINUTES LATITUDE (0-60)  ... 56.0 ...

 SECONDS LATITUDE (0-60)  ... 30.0 ...

 NORTH OR SOUTH  (N-S OR X)
  SELECT ITEM  .. N ..

 PHI  1 (STATION  1 LONGITUDE) ... -106.458
  DEGREES LONGITUDE (0-180)  ... 106.0 ...

 MINUTES LONGITUDE  (0-60)  ... 27.0 ...

 SECONDS LONGITUDE  (0-60)  ... 30.0 ...

 EAST OR WEST (E-W OR X)
  SELECT ITEM  .. W ..

 R  1 (STATION  1 RELIABILITY,0-1) ...  1.00000     ...
```

```
MU N 1, 1 (P -WAVE N LEVEL AT STAT  1) ...  5.00000     ...
 SIGMA N 1, 1 (P -WAVE N SD AT STAT  1) ... 0.109000     ...
 SIGMA S 1, 1 (P -WAVE SIG SD, STAT  1) ... 0.152000     ...
 R  1, 1 (P -WAVE SNR FOR STATION  1) ...  2.00000     ...
 S  1, 1 (P -WAVE ARIV TIME SD, STAT  1) ...  1.00000     ...
```

AD-A115 824   PACIFIC-SIERRA RESEARCH CORP SANTA MONICA CA   F/G 8/11
USERS' MANUAL FOR SNAP/D: SEISMIC NETWORK ASSESSMENT PROGRAM FO--ETC(U)
SEP 80   A P CIERVO, S K SANEMITSU, D E SNEAD   AC90-C-114
UNCLASSIFIED   PSR-1027   NL

2 of 2
AD
A115824

END
DATE
FILMED
7-82
DTIC

1.0 | 4.5 | 2.8 | 2.5
5.0 | 3.2 | 2.2
5.6 | 3.6
6.3 | 4.0 | 2.0
1.1 | 1.8
1.25 | 1.4 | 1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

```
MU N 2, 1 (PG-WAVE N LEVEL AT STAT  1) ...  5.00000     ...
 SIGMA N 2, 1 (PG-WAVE N SD AT STAT  1) ... 0.109000     ...
 SIGMA S 2, 1 (PG-WAVE SIG SD, STAT  1) ... 0.152000     ...
 R  2, 1 (PG-WAVE SNR FOR STATION  1) ...  2.00000     ...
 S  2, 1 (PG-WAVE ARIV TIME SD, STAT  1) ...  1.00000     ...
```

```
MU N 3, 1 (LG-WAVE N LEVEL AT STAT  1) ...  5.00000    ...
 SIGMA N 3, 1 (LG-WAVE N SD AT STAT  1) ... 0.109000    ...
 SIGMA S 3, 1 (LG-WAVE SIG SD, STAT  1) ... 0.152000    ...
 R  3, 1 (LG-WAVE SNR FOR STATION  1) ...  2.00000    ...
 SIGMA B 1 (LG-WAVE BACKAZ SD, STAT  1) ...  10.0000    ...
```

```
MU N 4, 1 (S -WAVE N LEVEL AT STAT  1) ...  5.00000     ...
 SIGMA N 4, 1 (S -WAVE N SD AT STAT  1) ... 0.109000     ...
 SIGMA S 4, 1 (S -WAVE SIG SD, STAT  1) ... 0.152000     ...
 R  4, 1 (S -WAVE SNR FOR STATION  1) ...  2.00000     ...
```

```
MU N S, 1 (PP-WAVE N LEVEL AT STAT  1) ...  5.00000     ...
 SIGMA N S, 1 (PP-WAVE N SD AT STAT  1) ... 0.109000     ...
 SIGMA S S, 1 (PP-WAVE SIG SD, STAT  1) ... 0.152000     ...
 R  S, 1 (PP-WAVE SNR FOR STATION  1) ...  2.00000     ...
 S  S, 1 (PP-WAVE ARIV TIME SD, STAT  1) ...  1.00000     ...
```

```
MU N 6, 1 (R -WAVE N LEVEL AT STAT  1) ...  10.0000    ...
 SIGMA N 6, 1 (R -WAVE N SD AT STAT  1) ... 0.109000    ...
 SIGMA S 6, 1 (R -WAVE SIG SD, STAT  1) ... 0.152000    ...
 R  6, 1 (R -WAVE SNR FOR STATION  1) ...  2.00000    ...
```

```
FOR STATION SPECIFIC DATA ENTER STATION NO(1-75) OR X ...   1 ...
 2
  STATION  2 NAME (4 CHARACTERS) .... CHTO ....

 THETA  2 (STATION  2 LATITUDE) ...  18.7900
  DEGREES LATITUDE (0-90)  ... 18.0 ...

 MINUTES LATITUDE (0-60)  ... 47.0 ...

 SECONDS LATITUDE (0-60)  ... 24.0 ...

 NORTH OR SOUTH  (N-S OR X)
  SELECT ITEM  .. N ..

 PHI  2 (STATION  2 LONGITUDE) ...  98.8103
  DEGREES LONGITUDE (0-180)  ...  98.0 ...

 MINUTES LONGITUDE  (0-60)  ... 48.0 ...

 SECONDS LONGITUDE  (0-60)  ... 37.0 ...

 EAST OR WEST (E-W OR X)
  SELECT ITEM  .. E ..

 R  2 (STATION  2 RELIABILITY,0-1) ...  1.00000     ...
```

```
MU N 1, 2 (P -WAVE N LEVEL AT STAT  2) ...  5.00000     ...
 SIGMA N 1, 2 (P -WAVE N SD AT STAT  2) ... 0.109000     ...
 SIGMA S 1, 2 (P -WAVE SIG SD, STAT  2) ... 0.152000     ...
 R  1, 2 (P -WAVE SNR FOR STATION  2) ...  2.00000     ...
 S  1, 2 (P -WAVE ARIV TIME SD, STAT  2) ...  1.00000     ...
```

```
MU N 2, 2 (PG-WAVE N LEVEL AT STAT  2) ...  5.00000    ...
 SIGMA N 2, 2 (PG-WAVE N SD AT STAT  2) ... 0.109000    ...
 SIGMA S 2, 2 (PG-WAVE SIG SD, STAT  2) ... 0.152000    ...
 R  2, 2 (PG-WAVE SNR FOR STATION  2) ...  2.00000    ...
 S  2, 2 (PG-WAVE ARIV TIME SD, STAT  2) ...  1.00000    ...
```

```
MU N 3, 2 (LG-WAVE N LEVEL AT STAT  2) ...  5.00000     ...
 SIGMA N 3, 2 (LG-WAVE N SD AT STAT  2) ... 0.109000     ...
 SIGMA S 3, 2 (LG-WAVE SIG SD, STAT  2) ... 0.152000     ...
 R  3, 2 (LG-WAVE SNR FOR STATION  2) ...  2.00000     ...
 SIGMA B 2 (LG-WAVE BACKAZ SD, STAT  2) ...  10.0000     ...
```

```
MU N 4, 2 (S -WAVE N LEVEL AT STAT  2) ...  5.00000     ...
 SIGMA N 4, 2 (S -WAVE N SD AT STAT  2) ... 0.109000     ...
 SIGMA S 4, 2 (S -WAVE SIG SD, STAT  2) ... 0.152000     ...
 R  4, 2 (S -WAVE SNR FOR STATION  2) ...  2.00000     ...
```

```
NU N S, 2 (PP-WAVE N LEVEL AT STAT  2) ...  5.00000     ...
 SIGMA N S, 2 (PP-WAVE N SD AT STAT  2) ... 0.109000     ...
 SIGMA S S, 2 (PP-WAVE SIG SD, STAT  2) ... 0.152000     ...
 R  S, 2 (PP-WAVE SNR FOR STATION  2) ...  2.00000     ...
 S  S, 2 (PP-WAVE ARIV TIME SD, STAT  2) ...  1.00000     ...
```

```
MU N 6, 2 (R -WAVE N LEVEL AT STAT  2) ...  10.0000     ...
 SIGMA N 6, 2 (R -WAVE N SD AT STAT  2) ... 0.109000     ...
 SIGMA S 6, 2 (R -WAVE SIG SD, STAT  2) ... 0.152000     ...
 R  6, 2 (R -WAVE SNR FOR STATION  2) ...  2.00000     ...
```

```
FOR STATION SPECIFIC DATA ENTER STATION NO(1-75) OR X ...   2 ...
 3
  STATION  3 NAME (4 CHARACTERS) .... GUMO ....

 THETA  3 (STATION  3 LATITUDE) ...  13.5878
  DEGREES LATITUDE (0-90)  ... 13.0 ...

 MINUTES LATITUDE (0-60)  ... 35.0 ...

 SECONDS LATITUDE (0-60)  ... 16.0 ...

 NORTH OR SOUTH  (N-S OR X)
  SELECT ITEM  .. N ..

 PHI  3 (STATION  3 LONGITUDE) ...  144.866
  DEGREES LONGITUDE (0-180)  ... 144.0 ...

 MINUTES LONGITUDE  (0-60)  ... 51.0 ...

 SECONDS LONGITUDE  (0-60)  ... 58.0 ...

 EAST OR WEST (E-W OR X)
  SELECT ITEM  .. E ..

 R  3 (STATION  3 RELIABILITY,0-1) ...  1.00000    ...
```

```
MU N 1, 3 (P -WAVE N LEVEL AT STAT  3) ...  5.00000     ...
 SIGMA N 1, 3 (P -WAVE N SD AT STAT  3) ... 0.109000     ...
 SIGMA S 1, 3 (P -WAVE SIG SD, STAT  3) ... 0.152000     ...
 R  1, 3 (P -WAVE SNR FOR STATION  3) ...  2.00000     ...
 S  1, 3 (P -WAVE ARIV TIME SD, STAT  3) ...  1.00000     ...
```

```
MU N 2, 3 (PG-WAVE N LEVEL AT STAT  3) ...  5.00000     ...
 SIGMA N 2, 3 (PG-WAVE N SD AT STAT  3) ... 0.109000     ...
 SIGMA S 2, 3 (PG-WAVE SIG SD, STAT  3) ... 0.152000     ...
 R  2, 3 (PG-WAVE SNR FOR STATION  3) ...  2.00000     ...
 S  2, 3 (PG-WAVE ARIV TIME SD, STAT  3) ...  1.00000     ...
```

```
MU N 3, 3 (LG-WAVE N LEVEL AT STAT  3) ...  5.00000     ...
 SIGMA N 3, 3 (LG-WAVE N SD AT STAT  3) ... 0.109000     ...
 SIGMA S 3, 3 (LG-WAVE SIG SD, STAT  3) ... 0.152000     ...
 R  3, 3 (LG-WAVE SNR FOR STATION  3) ...  2.00000     ...
 SIGMA B 3 (LG-WAVE BACKAZ SD, STAT  3) ...  10.0000     ...
```

```
MU N 4, 3 (S -WAVE N LEVEL AT STAT  3) ...  5.00000     ...
 SIGMA N 4, 3 (S -WAVE N SD AT STAT  3) ... 0.109000     ...
 SIGMA S 4, 3 (S -WAVE SIG SD, STAT  3) ... 0.152000     ...
 R  4, 3 (S -WAVE SNR FOR STATION  3) ...  2.00000     ...
```

```
MU N 5, 3 (PP-WAVE N LEVEL AT STAT  3) ...  5.00000     ...
 SIGMA N 5, 3 (PP-WAVE N SD AT STAT  3) ... 0.109000     ...
 SIGMA S 5, 3 (PP-WAVE SIG SD, STAT  3) ... 0.152000     ...
 R  5, 3 (PP-WAVE SNR FOR STATION  3) ...  2.00000     ...
 S  5, 3 (PP-WAVE ARIV TIME SD, STAT  3) ...  1.00000     ...
```

```
MU N 6, 3 (R -WAVE N LEVEL AT STAT  3) ...  10.0000     ...
 SIGMA N 6, 3 (R -WAVE N SD AT STAT  3) ... 0.109000     ...
 SIGMA S 6, 3 (R -WAVE SIG SD, STAT  3) ... 0.152000     ...
 R  6, 3 (R -WAVE SNR FOR STATION  3) ...  2.00000     ...
```

```
FOR STATICN SPECIFIC DATA ENTER STATION NO(1-75) OR X ...   3 ...
 X
  SNAP/D(TOPODF) STATION DATA
  SELECT ITEM  .. Q ..
 X
```

```
SNAP/D(TOPODF)

  TOPOGRAPHIC INPUTS

      0-STATION DATA
      1-EPICENTER GRID DATA
      2-EPICENTER/STATION CALIBRATION DATA
      3-REGIONAL GRID DATA
      4-IMPORTANCE MATRIX DATA
      X-EXIT TO MAIN MENU

  SELECT ITEM  .. 0 ..
 1

  A..            B..            C..             D.DISPLAY
  E..            F..            G..             H.HELP
  I.INITIALIZE   J..            K..             L.LOG ENABLE
  M.MENU         N.RESERVED     O.LOG DISABLE   P.PAUSE
  Q.WHERE        R.READ         S..             T..
  U.UPDATE       V..            W.WRITE         X.EXIT
  Y.RESERVED     Z.RESET        ;.LOG COMMENT

  SELECT ITEM  .. Q ..
 R
  FILE NAME .... NONE          ....
 TSTCSE.EPG
  TSTCSE.EPG   : EPICENTER GRID FILE (TSTCSE.EPG)
  SELECT ITEM  .. Q ..
 D
```

```
EPICENTER GRID FILE NAME: TSTCSE.EPG
  FILE DESCRIPTION .... EPICENTER GRID FILE (TSTCSE.EPG)
  ....

 N (NO. OF EPICENTER BLKS,0-10) ...   2 ...
```

```
JTHETA 1 (NO. OF EPIC LATS FOR BLK 1) ...  10 ...

JPHI 1 (NO. OF EPIC LONGS FOR BLK 1) ...  10 ...

THETA1, 1 (STARTING LAT FOR BLK 1) ...  43.0000
 DEGREES LATITUDE (0-90)  ... 43.0 ...

MINUTES LATITUDE (0-60)  ...  0.  ...

SECONDS LATITUDE (0-60)  ...  0.  ...

NORTH OR SOUTH  (N-S OR X)
 SELECT ITEM  .. N ..

DELTATHETA 1 (LAT EPIC SPACE FOR BLK 1) ...  1.00000     ...

PHI1, 1 (STARTING LONG FOR BLK 1) ...  72.0000
 DEGREES LONGITUDE (0-180)  ...  72.0 ...

MINUTES LONGITUDE  (0-60)  ...  0.  ...

SECONDS LONGITUDE  (0-60)  ...  0.  ...

EAST OR WEST (E-W OR X)
 SELECT ITEM  .. E ..

DELTAPHI 1 (LONG EPIC SPACE FOR BLK 1) ...  1.00000     ...
```

```
JTHETA 2 (NO. OF EPIC LATS FOR BLK 2) ...   8 ...

JPHI 2 (NO. OF EPIC LONGS FOR BLK 2) ...   9 ...

THETA1, 2 (STARTING LAT FOR BLK 2) ...  33.0000
 DEGREES LATITUDE (0-90)  ... 33.0 ...

MINUTES LATITUDE (0-60)  ...  0.  ...

SECONDS LATITUDE (0-60)  ...  0.  ...

NORTH OR SOUTH  (N-S OR X)
 SELECT ITEM  .. N ..

DELTATHETA 2 (LAT EPIC SPACE FOR BLK 2) ...  1.00000     ...

PHI1, 2 (STARTING LONG FOR BLK 2) ... -120.000
 DEGREES LONGITUDE (0-180)  ... 120.0 ...

MINUTES LONGITUDE  (0-60)  ...  0.  ...

SECONDS LONGITUDE  (0-60)  ...  0.  ...

EAST OR WEST (E-W OR X)
 SELECT ITEM  .. W ..

DELTAPHI 2 (LONG EPIC SPACE FOR BLK 2) ...  1.00000     ...

SNAP/D(TOPODF) EPICENTER GRID DATA
 SELECT ITEM  .. Q ..
x
```

```
SNAP/D(TOPODF)

  TOPOGRAPHIC INPUTS

      0-STATION DATA
      1-EPICENTER GRID DATA
      2-EPICENTER/STATION CALIBRATION DATA
      3-REGIONAL GRID DATA
      4-IMPORTANCE MATRIX DATA
      X-EXIT TO MAIN MENU

  SELECT ITEM  .. 1 ..
 2

  A..            B..            C..            D.DISPLAY
  E..            F..            G..            H.HELP
  I.INITIALIZE   J..            K..            L.LOG ENABLE
  M.MENU         N.RESERVED     O.LOG DISABLE  P.PAUSE
  Q.WHERE        R.READ         S..            T..
  U.UPDATE       V..            W.WRITE        X.EXIT
  Y.RESERVED     Z.RESET        ;.LOG COMMENT

  SELECT ITEM  .. Q ..
 R
  FILE NAME .... NONE           ....
 TSTCSE.ESC
  TSTCSE.ESC  : EPICENTER/STATION CALIB (TSTCSE.ESC)
  SELECT ITEM  .. Q ..
 D
```

```
EPICENTER/STATION CALIBRATION FILE NAME: TSTCSE.ESC
  FILE DESCRIPTION .... EPICENTER/STATION CALIB (TSTCSE.ESC)
  ....
```

```
EIJK (MAGNITUDE CORRECTION) ... -.200000
  FOR STATION  1 EPICENTER  87 WAVE TYPE  1
  CHANGE ? (Y-N-X)
  SELECT ITEM  .. N ..
```

```
EIJK (MAGNITUDE CORRECTION) ... -.900000E-01
  FOR STATION 22 EPICENTER  87 WAVE TYPE  1
  CHANGE ? (Y-N-X)
  SELECT ITEM  .. N ..

 OMEGAJ (MASTER-EVENT CALIB EPIC,1-400) ...   1 ...

 NO MASTER EVENT CALIBRATION
  OMEGAJ (MASTER-EVENT CALIB EPIC,1-400) ...   1 ...

 NO MASTER EVENT CALIBRATION
  OMEGAJ (MASTER-EVENT CALIB EPIC,1-400) ...   1 ...
 X
  PSIJ (S-P CALIBRATED EPIC,1-400) ...   1 ...

 NO S-P CALIBRATION
  PSIJ (S-P CALIBRATED EPIC,1-400) ...   1 ...

 NO S-P CALIBRATION
  PSIJ (S-P CALIBRATED EPIC,1-400) ...   1 ...
 X
  SNAP/D(TOPODF) EPICENTER-STATION CALIBRATION DATA
  SELECT ITEM  .. Q ..
 X
```

```
SNAP/D(TOPODF)

  TOPOGRAPHIC INPUTS

      0-STATION DATA
      1-EPICENTER GRID DATA
      2-EPICENTER/STATION CALIBRATION DATA
      3-REGIONAL GRID DATA
      4-IMPORTANCE MATRIX DATA
      X-EXIT TO MAIN MENU

  SELECT ITEM  .. 2 ..
 3

  A..            B..            C..            D.DISPLAY
  E..            F..            G..            H.HELP
  I.INITIALIZE   J..            K..            L.LOG ENABLE
  M.MENU         N.RESERVED     O.LOG DISABLE  P.PAUSE
  Q.WHERE        R.READ         S..            T..
  U.UPDATE       V..            W.WRITE        X.EXIT
  Y.RESERVED     Z.RESET        ;.LOG COMMENT

  SELECT ITEM  .. Q ..
 R
  FILE NAME .... NONE         ....
 TSTCSE.REG
  TSTCSE.REG  : REGIONAL GRID FILE (TSTCSE.REG)
  SELECT ITEM  .. Q ..
 D
```

```
REGION GRID FILE NAME: TSTCSE.REG
 FILE DESCRIPTION .... REGIONAL GRID FILE (TSTCSE.REG)
 ....

DELTA R (REG GRIC SIZE,2-20 DEG) ...  10.0000     ...

DELTA THETA C (POLAR CAP SIZE, DEG) ...  10.0000     ...

WN (NORTH POLAR CAP WT,0-1) ... 0.            ...

WS (SOUTH POLAR CAP WT,0-1) ... 0.            ...

ITEM-  3 FOR GRIC 298 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM-  4 FOR GRIC 299 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM-  5 FOR GRID 300 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM-  6 FOR GRIC 3C1 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM-  7 FOR GRID 302 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM-  8 FOR GRID 303 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM-  9 FOR GRID 304 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 10 FOR GRID 305 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 11 FOR GRID 306 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 12 FOR GRID 307 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 13 FOR GRIC 308 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 14 FOR GRID 309 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 15 FOR GRIC 334 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..
```

```
ITEM- 16 FOR GRIC 335 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 17 FOR GRIC 336 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 18 FOR GRID 337 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 19 FOR GRID 338 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 20 FOR GRID 339 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 21 FOR GRIC 340 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 22 FOR GRID 341 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 23 FOR GRID 342 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 24 FOR GRID 343 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 25 FOR GRIC 344 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 26 FOR GRID 345 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 27 FOR GRID 346 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 28 FOR GRIC 347 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 29 FOR GRID 348 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 30 FOR GRID 349 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 31 FOR GRID 380 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
```

```
 SELECT ITEM  .. N ..

ITEM- 32 FOR GRID 381 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 33 FOR GRID 382 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 34 FOR GRID 383 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 35 FOR GRID 384 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 36 FOR GRID 385 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 37 FOR GRID 418 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 38 FOR GRID 419 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 39 FOR GRID 420 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 40 FOR GRID 421 REGIONAL WT  1.00000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 41 FOR GRID 455 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 42 FOR GRID 456 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

ITEM- 43 FOR GRID 491 REGIONAL WT 0.500000
 CHANGE ? (Y-N OR X) ..
 SELECT ITEM  .. N ..

LIST GRID NOS. THAT SQUELCHES LG WAVES:
 LG SQUELCH GRID NO. ... 299 ...

LG SCUELCH GRID NO. ... 300 ...

LG SCUELCH GRID NO. ... 301 ...

LG SQUELCH GRID NO. ... 302 ...

LG SQUELCH GRID NO. ... 303 ...

LG SCUELCH GRID NO. ... 304 ...
```

```
LG SQUELCH GRID NO. ... 337 ...

LG SQUELCH GRID NO. ... 338 ...

LG SQUELCH GRID NO. ... 339 ...

SNAP/D(TOPODF) REGIONAL GRID DATA
 SELECT ITEM  .. Q ..
X
```

```
SNAP/D(TOPODF)

 TOPOGRAPHIC INPUTS

     0-STATION DATA
     1-EPICENTER GRID DATA
     2-EPICENTER/STATION CALIBRATION DATA
     3-REGIONAL GRID DATA
     4-IMPORTANCE MATRIX DATA
     X-EXIT TO MAIN MENU

 SELECT ITEM  .. 3 ..
4

 A..            B..            C..            D.DISPLAY
 E..            F..            G..            H.HELP
 I.INITIALIZE   J..            K..            L.LOG ENABLE
 M.MENU         N.RESERVED     O.LOG DISABLE  P.PAUSE
 Q.WHERE        R.READ         S..            T..
 U.UPDATE       V..            W.WRITE        X.EXIT
 Y.RESERVED     Z.RESET        ;.LOG COMMENT

 SELECT ITEM  .. Q ..
R
 FILE NAME .... NONE          ....
TSTCSE.IMM
 TSTCSE.IMM  : IMPORTANCES (TSTCSE.IMM)
 SELECT ITEM  .. Q ..
D
```

```
IMPORTANCE MATRIX FILE NAME: TSTCSE.IMM
  FILE DESCRIPTION .... IMPORTANCES (TSTCSE.IMM)
  ....
```

```
CREATE GAMMA  1 ( 1-TH IMPORTANCE MATRIX' EPICENTER SET)? (Y-N OR X)
  SELECT ITEM  .. N ..
 Y
  LIST EPICENTER INDICES FOR GAMMA  1 :
  EPICENTER INDEX ...    1 ...

 EPICENTER INDEX ...    2 ...

 EPICENTER INDEX ...    3 ...

 EPICENTER INDEX ...    4 ...

 EPICENTER INDEX ...    5 ...

 EPICENTER INDEX ...    6 ...

 EPICENTER INDEX ...    7 ...

 EPICENTER INDEX ...    8 ...

 EPICENTER INDEX ...    9 ...

 EPICENTER INDEX ...   10 ...

 EPICENTER INDEX ...   11 ...

 EPICENTER INDEX ...   12 ...

 EPICENTER INDEX ...   13 ...

 EPICENTER INDEX ...   14 ...

 EPICENTER INDEX ...   15 ...

 EPICENTER INDEX ...   16 ...

 EPICENTER INDEX ...   17 ...

 EPICENTER INDEX ...   18 ...

 EPICENTER INDEX ...   19 ...

 EPICENTER INDEX ...   20 ...

 EPICENTER INDEX ...   21 ...

 EPICENTER INDEX ...   22 ...

 EPICENTER INDEX ...   23 ...

 EPICENTER INDEX ...   24 ...

 EPICENTER INDEX ...   25 ...

 EPICENTER INDEX ...   26 ...

 EPICENTER INDEX ...   27 ...

 EPICENTER INDEX ...   28 ...

 EPICENTER INDEX ...   29 ...

 EPICENTER INDEX ...   30 ...
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EPICENTER INDEX ... 31 ...
EPICENTER INDEX ... 32 ...
EPICENTER INDEX ... 33 ...
EPICENTER INDEX ... 34 ...
EPICENTER INDEX ... 35 ...
EPICENTER INDEX ... 36 ...
EPICENTER INDEX ... 37 ...
EPICENTER INDEX ... 38 ...
EPICENTER INDEX ... 39 ...
EPICENTER INDEX ... 40 ...
EPICENTER INDEX ... 41 ...
EPICENTER INDEX ... 42 ...
EPICENTER INDEX ... 43 ...
EPICENTER INDEX ... 44 ...
EPICENTER INDEX ... 45 ...
EPICENTER INDEX ... 46 ...
EPICENTER INDEX ... 47 ...
EPICENTER INDEX ... 48 ...
EPICENTER INDEX ... 49 ...
EPICENTER INDEX ... 50 ...

```
SNAP/D(TOPODF)

  TOPOGRAPHIC INPUTS

       0-STATION DATA
       1-EPICENTER GRID DATA
       2-EPICENTER/STATION CALIBRATION DATA
       3-REGIONAL GRID DATA
       4-IMPORTANCE MATRIX DATA
       X-EXIT TO MAIN MENU

  SELECT ITEM  .. 4 ..
X
  SNAP/D(MAIN)
  SELECT ITEM  .. Q ..
C
                       PR(((P+PG)+LG)/4+P/4).

                       PR((P+LG+PG+LG)/4)+PR(P/4)-PR((P+LG+PG+LG)/4+P/4)

  PRINT SUMMARY FOR P  WAVE ? (Y-N OR X)
  SELECT ITEM  .. N ..
Y
  PRINT SUMMARY FOR PG WAVE ? (Y-N OR X)
  SELECT ITEM  .. N ..
Y
  PRINT SUMMARY FCR LG WAVE ? (Y-N OR X)
  SELECT ITEM  .. N ..
Y
  PRINT SUMMARY FCR S  WAVE ? (Y-N OR X)
  SELECT ITEM  .. N ..

 PRINT SUMMARY FOR PP WAVE ? (Y-N OR X)
  SELECT ITEM  .. N ..

 PRINT SUMMARY FOR R  WAVE ? (Y-N OR X)
  SELECT ITEM  .. N ..

 PRINT DETAILED EPICENTER INFO ? (Y-N OR X)
  SELECT ITEM  .. N ..
Y
  WAIT .....
```

AC90C114

<u>Sample Output</u>

```
DETECTION AND LOCATION RUN
PROB. EXPRESSION IS ((P+PG)+LG)/4+P/4
 NETWORK THRESH. PROB.= 0.90
 90 PERCENT ELLIPSES

GENERAL FILE NAMES

    DETECTION FILE (TSTCSE.DET)
    EPICENTER GRID FILE (TSTCSE.EPG)
    22 WORLDWIDE STATIONS (TSTCSE.STA)
    EPICENTER/STATION CALIB (TSTCSE.ESC)
    REGIONAL GRID FILE (TSTCSE.REG)
    IMPORTANCES (TSTCSE.IMM)

WAVE FILE NAMES

    WAVE INPUTS (TSTCSE.WAV)
      P WAVE FILE TEST (TSTCSE.X1)
        P-WAVE STABLE ATTEN. TABLE (TSTCSE.AS1)
        P-WAVE TECT. ATTEN. TABLE (TSTCSE.AT1)
        P-WAVE SHALLOW TRAVEL-TIME (TSTCSE.TS1)
        P-WAVE STANDARD DEVIATIONS (TSTCSE.SS1)
      PG WAVE FILE INPUTS (TSTCSE.X2)
        PG STABLE ATTENUATION TABLE (TSTCSE.AS2)
        PG TECTONIC ATTEN. TABLE (TSTCSE.AT2)
        PG TRAVEL-TIME TABLE (TSTCSE.TS2)
        PG TRAVEL-TIME STAND. DEVS. (TSTCSE.SS2)
      LG WAVE FILE INPUTS (TSTCSE.X3)
        LG STABLE ATTENUATION TABLE (TSTCSE.AS3)
        LG TECTONIC ATTEN. TABLE (TSTCSE.AT3)
      S WAVE FILE (TSTCSE.X4)
        S-WAVE STABLE ATTEN. TABLE (TSTCSE.AS4)
        S-WAVE TECT. ATTEN. TABLE (TSTCSE.AT4)
```

STATION TABLE (P-WV) SIGN CONVENTION +=N,E

I	IDENT	LAT.	LONG.	NOISE AMPL	NOISE SD	S/N RATIO	SD TIME	REL	SD SIG
1	ANMO	34.94	-106.46	5.00	0.11	2.00	1.00	1.00	0.15
2	CHTO	18.79	98.81	5.00	0.11	2.00	1.00	1.00	0.15
3	GUMO	13.59	144.87	5.00	0.11	2.00	1.00	1.00	0.15
4	MAIO	36.30	59.49	5.00	0.11	2.00	1.00	1.00	0.15
5	NWAO	-32.93	117.24	5.00	0.11	2.00	1.00	1.00	0.15
6	TATO	24.98	121.49	5.00	0.11	2.00	1.00	1.00	0.15
7	SNZO	-41.31	174.70	5.00	0.11	2.00	1.00	1.00	0.15
8	CTAO	-20.09	146.25	5.00	0.11	2.00	1.00	1.00	0.15
9	ZOBO	-16.27	-68.13	5.00	0.11	2.00	1.00	1.00	0.15
10	KAAO	34.54	69.04	5.00	0.11	2.00	1.00	1.00	0.15
11	MAJO	36.54	138.21	5.00	0.11	2.00	1.00	1.00	0.15
12	ATAK	52.88	173.17	5.00	0.11	2.00	1.00	1.00	0.15
13	UCAK	66.00	-153.72	5.00	0.11	2.00	1.00	1.00	0.15
14	CNAK	67.45	-144.52	5.00	0.11	2.00	1.00	1.00	0.15
15	TNAK	62.91	-156.02	5.00	0.11	2.00	1.00	1.00	0.15
16	BFAK	64.77	-146.89	5.00	0.11	2.00	1.00	1.00	0.15
17	NJAK	63.06	-141.83	5.00	0.11	2.00	1.00	1.00	0.15
18	HNME	46.16	-67.99	5.00	0.11	2.00	1.00	1.00	0.15
19	RKON	50.34	-93.67	5.00	0.11	2.00	1.00	1.00	0.15
20	KSRS	37.45	127.92	5.00	0.11	2.00	1.00	1.00	0.15
21	ILPA	35.42	50.69	5.00	0.11	2.00	1.00	1.00	0.15
22	NAO	60.82	10.82	5.00	0.11	2.00	1.00	1.00	0.15

STATION TABLE (PG-W)   SIGN CONVENTION +=N,E

I	IDENT	LAT.	LONG.	NOISE AMPL	NOISE SD	S/N RATIO	SD TIME	REL	SD SIG
1	ANMO	34.94	-106.46	5.00	0.11	2.00	1.00	1.00	0.15
2	CHTO	18.79	98.81	5.00	0.11	2.00	1.00	1.00	0.15
3	GUMO	13.59	144.87	5.00	0.11	2.00	1.00	1.00	0.15
4	MAIO	36.30	59.49	5.00	0.11	2.00	1.00	1.00	0.15
5	NWAO	-32.93	117.24	5.00	0.11	2.00	1.00	1.00	0.15
6	TATO	24.98	121.49	5.00	0.11	2.00	1.00	1.00	0.15
7	SNZO	-41.31	174.70	5.00	0.11	2.00	1.00	1.00	0.15
8	CTAO	-20.09	146.25	5.00	0.11	2.00	1.00	1.00	0.15
9	ZOBO	-16.27	-68.13	5.00	0.11	2.00	1.00	1.00	0.15
10	KAAO	34.54	69.04	5.00	0.11	2.00	1.00	1.00	0.15
11	MAJO	36.54	138.21	5.00	0.11	2.00	1.00	1.00	0.15
12	ATAK	52.88	173.17	5.00	0.11	2.00	1.00	1.00	0.15
13	UCAK	66.00	-153.72	5.00	0.11	2.00	1.00	1.00	0.15
14	CNAK	67.45	-144.52	5.00	0.11	2.00	1.00	1.00	0.15
15	TNAK	62.91	-156.02	5.00	0.11	2.00	1.00	1.00	0.15
16	BFAK	64.77	-146.89	5.00	0.11	2.00	1.00	1.00	0.15
17	NJAK	63.06	-141.83	5.00	0.11	2.00	1.00	1.00	0.15
18	MNME	46.16	-67.99	5.00	0.11	2.00	1.00	1.00	0.15
19	RKON	50.34	-93.67	5.00	0.11	2.00	1.00	1.00	0.15
20	KSRS	37.45	127.92	5.00	0.11	2.00	1.00	1.00	0.15
21	ILPA	35.42	50.69	5.00	0.11	2.00	1.00	1.00	0.15
22	NAO	60.82	10.82	5.00	0.11	2.00	1.00	1.00	0.15

STATION TABLE (LG-W)   SIGN CONVENTION +=N,E

I	IDENT	LAT.	LONG.	NOISE AMPL	NOISE SD	S/N RATIO	SD TIME	REL	SD SIG
1	ANMO	34.94	-106.46	5.00	0.11	2.00	10.00	1.00	0.15
2	CHTO	18.79	98.81	5.00	0.11	2.00	10.00	1.00	0.15
3	GUMO	13.59	144.87	5.00	0.11	2.00	10.00	1.00	0.15
4	MAIO	36.30	59.49	5.00	0.11	2.00	10.00	1.00	0.15
5	NWAO	-32.93	117.24	5.00	0.11	2.00	10.00	1.00	0.15
6	TATO	24.98	121.49	5.00	0.11	2.00	10.00	1.00	0.15
7	SNZO	-41.31	174.70	5.00	0.11	2.00	10.00	1.00	0.15
8	CTAO	-20.09	146.25	5.00	0.11	2.00	10.00	1.00	0.15
9	ZOBO	-16.27	-68.13	5.00	0.11	2.00	10.00	1.00	0.15
10	KAAO	34.54	69.04	5.00	0.11	2.00	10.00	1.00	0.15
11	MAJO	36.54	138.21	5.00	0.11	2.00	10.00	1.00	0.15
12	ATAK	52.88	173.17	5.00	0.11	2.00	10.00	1.00	0.15
13	UCAK	66.00	-153.72	5.00	0.11	2.00	10.00	1.00	0.15
14	CNAK	67.45	-144.52	5.00	0.11	2.00	10.00	1.00	0.15
15	TNAK	62.91	-156.02	5.00	0.11	2.00	10.00	1.00	0.15
16	BFAK	64.77	-146.89	5.00	0.11	2.00	10.00	1.00	0.15
17	NJAK	63.06	-141.83	5.00	0.11	2.00	10.00	1.00	0.15
18	HNME	46.16	-67.99	5.00	0.11	2.00	10.00	1.00	0.15
19	RKON	50.34	-93.67	5.00	0.11	2.00	10.00	1.00	0.15
20	KSRS	37.45	127.92	5.00	0.11	2.00	10.00	1.00	0.15
21	ILPA	35.42	50.69	5.00	0.11	2.00	10.00	1.00	0.15
22	NAO	60.82	10.82	5.00	0.11	2.00	10.00	1.00	0.15

STATION TABLE (S-WV) SIGN CONVENTION +=N,E

I	IDENT	LAT.	LONG.	NOISE AMPL	NOISE SD	S/N RATIO	SD TIME	REL	SD SIG
1	ANMO	34.94	-106.46	5.00	0.11	2.00	0.	1.00	0.15
2	CMTC	18.79	98.81	5.00	0.11	2.00	0.	1.00	0.15
3	GUMO	13.59	144.87	5.00	0.11	2.00	0.	1.00	0.15
4	MAIO	36.30	59.49	5.00	0.11	2.00	0.	1.00	0.15
5	NWAO	-32.93	117.24	5.00	0.11	2.00	0.	1.00	0.15
6	TATO	24.98	121.49	5.00	0.11	2.00	0.	1.00	0.15
7	SNZO	-41.31	174.70	5.00	0.11	2.00	0.	1.00	0.15
8	CTAO	-20.09	146.25	5.00	0.11	2.00	0.	1.00	0.15
9	ZOBO	-16.27	-68.13	5.00	0.11	2.00	0.	1.00	0.15
10	KAAO	34.54	69.04	5.00	0.11	2.00	0.	1.00	0.15
11	MAJO	36.54	138.21	5.00	0.11	2.00	0.	1.00	0.15
12	ATAK	52.85	173.17	5.00	0.11	2.00	0.	1.00	0.15
13	UCAK	66.00	-153.72	5.00	0.11	2.00	0.	1.00	0.15
14	CNAK	67.45	-144.52	5.00	0.11	2.00	0.	1.00	0.15
15	TNAK	62.91	-156.02	5.00	0.11	2.00	0.	1.00	0.15
16	BFAK	64.77	-146.89	5.00	0.11	2.00	0.	1.00	0.15
17	NJAK	63.06	-141.83	5.00	0.11	2.00	0.	1.00	0.15
18	MNME	46.16	-67.99	5.00	0.11	2.00	0.	1.00	0.15
19	RKON	50.34	-93.67	5.00	0.11	2.00	0.	1.00	0.15
20	KSRS	37.45	127.92	5.00	0.11	2.00	0.	1.00	0.15
21	ILPA	35.42	50.69	5.00	0.11	2.00	0.	1.00	0.15
22	NAO	60.82	10.82	5.00	0.11	2.00	0.	1.00	0.15

P-WV STABLE ATTENUATION TABLE

DEG	B	C	DEG	B	C	DEG	B	C	DEG	B	C
0.	0.	0.	27.00	-3.50	0.	54.00	-3.80	0.	81.00	-3.80	0.
1.00	0.	0.	28.00	-3.60	0.	55.00	-3.80	0.	82.00	-3.90	0.
2.00	-2.20	0.	29.00	-3.60	0.	56.00	-3.80	0.	83.00	-4.00	0.
3.00	-2.70	0.	30.00	-3.60	0.	57.00	-3.80	0.	84.00	-4.00	0.
4.00	-3.10	0.	31.00	-3.70	0.	58.00	-3.80	0.	85.00	-4.00	0.
5.00	-3.40	0.	32.00	-3.70	0.	59.00	-3.80	0.	86.00	-3.90	0.
6.00	-3.60	0.	33.00	-3.70	0.	60.00	-3.80	0.	87.00	-4.00	0.
7.00	-3.80	0.	34.00	-3.70	0.	61.00	-3.90	0.	88.00	-4.10	0.
8.00	-4.00	0.	35.00	-3.70	0.	62.00	-4.00	0.	89.00	-4.00	0.
9.00	-4.20	0.	36.00	-3.60	0.	63.00	-3.90	0.	90.00	-4.00	0.
10.00	-4.30	0.	37.00	-3.50	0.	64.00	-4.00	0.	91.00	-4.10	0.
11.00	-4.20	0.	38.00	-3.50	0.	65.00	-4.00	0.	92.00	-4.10	0.
12.00	-4.10	0.	39.00	-3.40	0.	66.00	-4.00	0.	93.00	-4.20	0.
13.00	-4.00	0.	40.00	-3.40	0.	67.00	-4.00	0.	94.00	-4.10	0.
14.00	-3.60	0.	41.00	-3.50	0.	68.00	-4.00	0.	95.00	-4.20	0.
15.00	-3.30	0.	42.00	-3.50	0.	69.00	-4.00	0.	96.00	-4.30	0.
16.00	-2.90	0.	43.00	-3.50	0.	70.00	-3.90	0.	97.00	-4.40	0.
17.00	-2.90	0.	44.00	-3.50	0.	71.00	-3.90	0.	98.00	-4.50	0.
18.00	-2.90	0.	45.00	-3.70	0.	72.00	-3.90	0.	99.00	-4.50	0.
19.00	-3.00	0.	46.00	-3.80	0.	73.00	-3.90	0.	100.00	-4.40	0.
20.00	-3.00	0.	47.00	-3.90	0.	74.00	-3.80	0.	101.00	-4.30	0.
21.00	-3.10	0.	48.00	-3.90	0.	75.00	-3.80	0.	102.00	-4.40	0.
22.00	-3.20	0.	49.00	-3.80	0.	76.00	-3.90	0.	103.00	-4.50	0.
23.00	-3.30	0.	50.00	-3.70	0.	77.00	-3.90	0.	104.00	-4.60	0.
24.00	-3.30	0.	51.00	-3.70	0.	78.00	-3.90	0.	105.00	-4.70	0.
25.00	-3.50	0.	52.00	-3.70	0.	79.00	-3.80	0.			
26.00	-3.40	0.	53.00	-3.70	0.	80.00	-3.70	0.			

P-WV TECTONIC ATTENUATION TABLE

DEG	B	C	DEG	B	C	DEG	B	C	DEG	B	C
0.	2.20	0.	6.00	3.90	0.	12.00	4.40	0.	18.00	3.20	0.
1.00	2.20	0.	7.00	4.10	0.	13.00	4.30	0.	19.00	3.30	0.
2.00	2.50	0.	8.00	4.30	0.	14.00	3.90	0.	20.00	3.30	0.
3.00	3.00	0.	9.00	4.50	0.	15.00	3.60	0.			
4.00	3.40	0.	10.00	4.60	0.	16.00	3.20	0.			
5.00	3.70	0.	11.00	4.50	0.	17.00	3.20	0.			

P-WV TRAVEL-TIME TABLE

DEG	SEC	DEG	SEC	DEG	SEC	DEG	SEC
0.	0.	46.	504.28	92.	790.06	138.	1166.50
1.	21.14	47.	512.12	93.	794.69	139.	1168.30
2.	34.86	48.	519.89	94.	799.30	140.	1170.10
3.	48.58	49.	527.58	95.	803.89	141.	1171.90
4.	62.29	50.	535.20	96.	808.47	142.	1173.70
5.	75.99	51.	542.74	97.	813.06	143.	1175.40
6.	89.67	52.	550.22	98.	817.60	144.	1177.10
7.	103.34	53.	557.62	99.	822.17	145.	1178.80
8.	116.98	54.	564.95	100.	826.73	146.	1180.50
9.	130.60	55.	572.21	101.	-1.00	147.	1182.10
10.	144.19	56.	579.40	102.	-1.00	148.	1183.70
11.	157.75	57.	586.51	103.	-1.00	149.	1185.30
12.	171.28	58.	593.55	104.	-1.00	150.	1186.80
13.	184.77	59.	600.52	105.	-1.00	151.	1188.30
14.	198.19	60.	607.42	106.	-1.00	152.	1189.80
15.	211.48	61.	614.24	107.	-1.00	153.	1191.20
16.	224.55	62.	621.01	108.	-1.00	154.	1192.60
17.	237.34	63.	627.71	109.	-1.00	155.	1193.90
18.	249.78	64.	634.35	110.	1110.50	156.	1195.30
19.	261.79	65.	640.91	111.	1114.90	157.	1196.60
20.	273.32	66.	647.41	112.	1116.80	158.	1197.80
21.	284.37	67.	653.85	113.	1118.70	159.	1198.90
22.	294.95	68.	660.22	114.	1120.70	160.	1200.00
23.	305.11	69.	666.51	115.	1122.60	161.	1201.00
24.	314.91	70.	672.74	116.	1124.50	162.	1202.00
25.	324.39	71.	678.88	117.	1126.40	163.	1203.00
26.	333.63	72.	684.94	118.	1128.30	164.	1204.00
27.	342.71	73.	690.91	119.	1130.20	165.	1204.90
28.	351.68	74.	696.81	120.	1132.10	166.	1205.70
29.	360.60	75.	[illegible]02.63	121.	1134.00	167.	1206.50
30.	369.51	76.	[illegible]8.38	122.	1135.90	168.	1207.20
31.	378.38	77.	[illegible]14.07	123.	1137.80	169.	1207.80
32.	387.19	78.	719.67	124.	1139.80	170.	1208.40
33.	395.96	79.	725.19	125.	1141.70	171.	1208.90
34.	404.68	80.	730.63	126.	1143.70	172.	1209.30
35.	413.34	81.	736.00	127.	1145.60	173.	1209.70
36.	421.95	82.	741.29	128.	1147.50	174.	1210.10
37.	430.49	83.	746.49	129.	1149.40	175.	1210.40
38.	438.96	84.	751.61	130.	1151.30	176.	1210.60
39.	447.37	85.	756.63	131.	1153.20	177.	1210.80
40.	455.70	86.	761.56	132.	1155.10	178.	1210.90
41.	463.97	87.	766.43	133.	1157.00	179.	1211.00
42.	472.17	88.	771.25	134.	1158.90	180.	1211.00
43.	480.31	89.	776.01	135.	1160.80		
44.	488.37	90.	780.72	136.	1162.70		
45.	496.36	91.	785.40	137.	1164.60		

P-WV TRAVEL-TIME
DISTANCE VS STD. DEV.

DEG	SEC	DEG	SEC	DEG	SEC	DEG	SEC
0.	0.	13.	2.96	26.	1.39	98.	0.94
1.	0.80	14.	2.90	27.	1.36	99.	1.00
2.	1.30	15.	2.77	28.	1.34	100.	1.10
3.	1.70	16.	2.58	29.	1.32	101.	1.21
4.	2.00	17.	2.38	30.	1.30	102.	1.33
5.	2.25	18.	2.17	60.	1.60	103.	1.46
6.	2.47	19.	1.98	90.	0.80	104.	1.60
7.	2.66	20.	1.81	92.	0.80	105.	1.75
8.	2.78	21.	1.69	93.	0.81	106.	1.91
9.	2.88	22.	1.69	94.	0.82	107.	2.00
10.	2.96	23.	1.54	95.	0.84	180.	2.00
11.	3.06	24.	1.48	96.	0.87		
12.	3.00	25.	1.43	97.	0.90		

PG-W STABLE ATTENUATION TABLE

DEG	B	C	DEG	B	C	DEG	B	C	DEG	B	C
0.10	3.72	0.	0.50	1.27	0.	2.00	-0.83	0.	10.00	-3.28	0.
0.20	2.67	0.	1.00	0.22	0.	5.00	-2.23	0.	20.00	-4.33	0.

PG-W TECTONIC ATTENUATION TABLE

DEG	B	C	DEG	B	C	DEG	B	C	DEG	B	C
0.10	3.72	0.	0.50	0.98	0.	2.00	-2.13	0.	10.00	-5.28	0.
0.20	2.37	0.	1.00	-0.78	0.	5.00	-3.92	0.	20.00	-6.63	0.

PG-W TRAVEL-TIME TABLE

DEG	SEC	DEG	SEC	DEG	SEC	DEG	SEC
0.	0.	8.	150.38	16.	307.76	24.	464.64
1.	18.53	9.	170.99	17.	327.87	25.	484.75
2.	37.06	10.	191.10	18.	347.98	26.	501.86
3.	55.59	11.	211.21	19.	368.09	27.	521.97
4.	74.12	12.	231.32	20.	387.20	28.	541.08
5.	91.55	13.	249.43	21.	406.31		
6.	110.66	14.	269.54	22.	426.42		
7.	129.77	15.	287.65	23.	445.53		

PG-W TRAVEL-TIME
DISTANCE VS STD. DEV.

DEG	SEC	DEG	SEC	DEG	SEC	DEG	SEC
0.	0.	6.	3.00	12.	3.00	18.	3.00
1.	0.50	7.	3.00	13.	3.00	19.	3.00
2.	1.00	8.	3.00	14.	3.00	20.	3.00
3.	1.50	9.	3.00	15.	3.00		
4.	2.00	10.	3.00	16.	3.00		
5.	2.50	11.	3.00	17.	3.00		

LG-W STABLE ATTENUATION TABLE

DEG	B	C	DEG	B	C	DEG	B	C	DEG	B	C
0.10	3.90	0.	0.50	1.45	0.	2.00	-0.65	0.	10.00	-3.10	0.
0.20	2.84	0.	1.00	0.40	0.	5.00	-2.05	0.	20.00	-4.15	0.

LG-W TECTONIC ATTENUATION TABLE

DEG	B	C	DEG	B	C	DEG	B	C	DEG	B	C
0.10	3.90	0.	0.50	0.76	0.	2.00	-1.95	0.	10.00	-5.10	0.
0.20	2.55	0.	1.00	-0.60	0.	5.00	-3.74	0.	20.00	-6.45	0.

S-WV STABLE ATTENUATION TABLE

DEG	B	C	DEG	B	C	DEG	B	C	DEG	B	C
0.10	3.40	0.	5.00	-1.87	0.	50.00	-3.70	0.	100.00	-4.20	0.
0.20	2.47	0.	10.00	-2.80	0.	60.00	-3.80	0.	105.00	-4.20	0.
0.50	1.23	0.	20.00	-3.73	0.	70.00	-3.90	0.			
1.00	0.30	0.	30.00	-3.50	0.	80.00	-4.00	0.			
2.00	-0.63	0.	40.00	-3.60	0.	90.00	-4.10	0.			

S-WV TECTONIC ATTENUATION TABLE

DEG	B	C	DEG	B	C	DEG	B	C	DEG	B	C
0.10	3.40	0.	0.50	0.60	0.	2.00	-1.81	0.	10.00	-4.60	0.
0.20	2.19	0.	1.00	-0.60	0.	5.00	-3.40	0.	20.00	-5.81	0.

EPICENTER 1 LAT=43.0N LONG= 72.0E THRESH. MAG= 4.67

STATION	ANG. DIST	AZM.	P-WV SD TIME	P-WV PROB	PG-W SD TIME	PG-W PROB	LG-W SD TIME	LG-W PROB	S-WV SD TIME	S-WV PROB
1 ANMO	102.05	358.71	1.830	0.000	1.250	0.	0.	0.	0.	0.050
2 CHTO	33.11	128.58	1.828	0.427	1.250	0.	0.	0.	0.	0.279
3 GUMO	68.31	91.45	1.895	0.037	1.250	0.	0.	0.	0.	0.126
4 MAIO	11.71	239.30	3.266	0.007	3.250	0.592	0.	0.391	0.	0.597
5 NWAO	86.47	143.34	1.558	0.066	1.250	0.	0.	0.	0.	0.076
6 TATO	44.06	97.67	1.913	0.794	1.250	0.	0.	0.	0.	0.224
7 SNZO	124.82	116.80	2.358	0.	1.250	0.	0.	0.	0.	0.
8 CTAO	92.74	115.18	1.488	0.003	1.250	0.	0.	0.	0.	0.063
9 ZOBO	136.88	295.80	2.358	0.	1.250	0.	0.	0.	0.	0.
10 KAAO	8.77	196.19	3.118	0.004	3.250	0.824	0.	0.663	0.	0.806
11 MAJO	49.98	73.74	1.958	0.422	1.250	0.	0.	0.	0.	0.198
12 ATAK	62.72	41.76	1.987	0.081	1.250	0.	0.	0.	0.	0.146
13 UCAK	65.46	18.67	1.942	0.037	1.250	0.	0.	0.	0.	0.136
14 CNAK	66.14	14.45	1.931	0.037	1.250	0.	0.	0.	0.	0.133
15 TNAK	67.40	21.51	1.910	0.037	1.250	0.	0.	0.	0.	0.129
16 BFAK	68.02	16.77	1.900	0.037	1.250	0.	0.	0.	0.	0.127
17 NJAK	70.56	15.51	1.856	0.105	1.250	0.	0.	0.	0.	0.119
18 MNME	84.03	333.40	1.608	0.037	1.250	0.	0.	0.	0.	0.082
19 RKON	85.83	350.89	1.571	0.089	1.250	0.	0.	0.	0.	0.077
20 KSRS	42.27	77.86	1.900	0.812	1.250	0.	0.	0.	0.	0.233
21 ILPA	18.10	252.40	2.488	1.000	3.250	0.207	0.	0.092	0.	0.247
22 NAO	39.85	318.23	1.881	0.922	1.250	0.	0.	0.	0.	0.245

ERROR...ST 1 PHASE P EVENT X ANG DIST IS OUT OF TABLE RANGE 102.046

EPICENTER 2 LAT=43.0N LONG= 73.0E THRESH. MAG= 4.67

STATION	ANG. DIST	AZM.	P-WV SD TIME	P-WV PROB	PG-W SD TIME	PG-W PROB	LG-W SD TIME	LG-W PROB	S-WV SD TIME	S-WV PROB
1 ANMO	102.06	359.55	1.831	0.000	1.250	0.	0.	0.	0.	0.051
2 CHTO	32.54	129.98	1.824	0.445	1.250	0.	0.	0.	0.	0.287
3 GUMO	67.57	92.14	1.907	0.041	1.250	0.	0.	0.	0.	0.132
4 MAIO	12.35	241.67	3.237	0.019	3.250	0.547	0.	0.348	0.	0.558
5 NWAO	86.04	144.06	1.567	0.110	1.250	0.	0.	0.	0.	0.079
6 TATO	43.33	98.46	1.908	0.824	1.250	0.	0.	0.	0.	0.231
7 SNZO	124.17	117.25	2.358	0.	1.250	0.	0.	0.	0.	0.
8 CTAO	92.08	115.85	1.485	0.010	1.250	0.	0.	0.	0.	0.066
9 ZOBO	137.53	296.83	2.358	0.	1.250	0.	0.	0.	0.	0.
10 KAAO	9.00	201.31	3.140	0.002	3.250	0.811	0.	0.645	0.	0.794
11 MAJO	49.27	74.25	1.952	0.300	1.250	0.	0.	0.	0.	0.204
12 ATAK	62.23	42.16	1.995	0.053	1.250	0.	0.	0.	0.	0.151
13 UCAK	65.22	19.04	1.946	0.041	1.250	0.	0.	0.	0.	0.140
14 CNAK	65.96	14.82	1.934	0.041	1.250	0.	0.	0.	0.	0.137
15 TNAK	67.13	21.91	1.915	0.041	1.250	0.	0.	0.	0.	0.133
16 BFAK	67.81	17.17	1.903	0.041	1.250	0.	0.	0.	0.	0.131
17 NJAK	70.37	15.94	1.860	0.114	1.250	0.	0.	0.	0.	0.123
18 HNME	84.36	334.01	1.601	0.041	1.250	0.	0.	0.	0.	0.083
19 RKON	85.94	351.52	1.569	0.108	1.250	0.	0.	0.	0.	0.079
20 KSRS	41.55	78.38	1.894	0.824	1.250	0.	0.	0.	0.	0.241
21 ILPA	18.80	253.72	2.374	1.000	3.250	0.186	0.	0.080	0.	0.226
22 NAO	40.37	318.27	1.885	0.898	1.250	0.	0.	0.	0.	0.247

ERROR...ST 1 PHASE P EVENT X ANG DIST IS OUT OF TABLE RANGE 102.057

EPICENTER 3 LAT=43.0N LONG=.74.0E THRESH. MAG= 4.68

STATION	ANG. DIST	AZM.	P-WV SD TIME	P-WV PROB	PG-W SD TIME	PG-W PROB	LG-W SD TIME	LG-W PROB	S-WV SD TIME	S-WV PROB
1 ANMC	102.06	0.38	1.831	0.000	1.250	0.	0.	0.	0.	0.053
2 CHTO	31.99	131.42	1.819	0.467	1.250	0.	0.	0.	0.	0.295
3 GUMO	66.84	92.83	1.920	0.046	1.250	0.	0.	0.	0.	0.138
4 MAIO	13.00	243.84	3.213	0.046	3.250	0.505	0.	0.310	0.	0.521
5 NWAO	85.61	144.78	1.576	0.087	1.250	0.	0.	0.	0.	0.082
6 TATO	42.61	99.26	1.902	0.838	1.250	0.	0.	0.	0.	0.240
7 SNZO	123.52	117.71	2.358	0.	1.250	0.	0.	0.	0.	0.
8 CTAC	91.43	116.52	1.484	0.013	1.250	0.	0.	0.	0.	0.069
9 ZOBO	133.18	297.89	2.358	0.	1.250	0.	0.	0.	0.	0.
10 KAAO	9.30	206.15	3.162	0.002	3.250	0.794	0.	0.622	0.	0.779
11 MAJO	48.57	74.76	1.947	0.199	1.250	0.	0.	0.	0.	0.212
12 ATAK	61.74	42.56	2.003	0.061	1.250	0.	0.	0.	0.	0.157
13 UCAK	64.98	19.40	1.950	0.046	1.250	0.	0.	0.	0.	0.144
14 CNAK	65.77	15.18	1.937	0.046	1.250	0.	0.	0.	0.	0.141
15 TNAK	66.85	22.30	1.919	0.046	1.250	0.	0.	0.	0.	0.138
16 BFAK	67.59	17.57	1.907	0.046	1.250	0.	0.	0.	0.	0.135
17 NJAK	70.16	16.37	1.863	0.125	1.250	0.	0.	0.	0.	0.127
18 HNME	84.67	334.63	1.595	0.046	1.250	0.	0.	0.	0.	0.085
19 RKON	86.04	352.15	1.567	0.120	1.250	0.	0.	0.	0.	0.081
20 KSRS	40.83	78.89	1.889	0.859	1.250	0.	0.	0.	0.	0.250
21 ILPA	19.51	254.97	2.271	1.000	3.250	0.167	0.	0.070	0.	0.208
22 NAO	40.86	318.31	1.889	0.856	1.250	0.	0.	0.	0.	0.249

ERROR...ST 1 PHASE P EVENT X ANG DIST IS OUT OF TABLE RANGE 102.057

NETWORK LOCATION SUMMARY
(MAGNITUDES RANGE FROM 3.00 TO 6.00)

	LAT.	LONG.	MAG	MAJR(KM)	MINR(KM)	STRIKE	AREA	DEPTH
1	43.00N	72.00E	4.67	60.78	28.54	19.84	5449.17	131.85
2	43.00N	73.00E	4.67	60.62	28.41	18.47	5409.77	137.56
3	43.00N	74.00E	4.68	58.97	28.42	17.53	5265.70	133.64
4	43.00N	75.00E	4.66	59.03	28.64	13.61	5311.27	129.34
5	43.00N	76.00E	4.62	63.92	28.50	10.09	5721.95	145.81
6	43.00N	77.00E	4.58	62.64	28.73	8.66	5654.98	132.30
7	43.00N	78.00E	4.57	61.90	28.51	9.33	5543.27	131.95
8	43.00N	79.00E	4.57	61.75	28.13	8.50	5457.44	131.46
9	43.00N	80.00E	4.57	60.25	28.08	7.93	5315.04	151.65
10	43.00N	81.00E	4.59	58.57	28.06	7.89	5163.79	151.04
11	44.00N	72.00E	4.68	61.64	28.49	17.40	5516.83	142.09
12	44.00N	73.00E	4.68	59.36	28.56	17.02	5325.79	136.64
13	44.00N	74.00E	4.67	56.66	28.53	15.59	5079.15	124.25
14	44.00N	75.00E	4.63	60.42	28.71	10.03	5448.98	143.61
15	44.00N	76.00E	4.60	63.18	29.03	6.91	5762.56	146.09
16	44.00N	77.00E	4.59	62.52	29.08	6.26	5710.94	135.44
17	44.00N	78.00E	4.58	61.81	28.59	6.69	5551.96	134.63
18	44.00N	79.00E	4.57	60.41	28.61	7.46	5428.86	154.36
19	44.00N	80.00E	4.56	60.07	28.17	6.87	5315.30	157.36
20	44.00N	81.00E	4.59	56.35	27.72	7.67	4907.45	133.85
21	45.00N	72.00E	4.69	59.02	28.60	16.17	5303.16	140.04
22	45.00N	73.00E	4.67	56.30	28.76	15.52	5085.97	126.98
23	45.00N	74.00E	4.63	57.04	29.05	10.52	5205.30	133.28
24	45.00N	75.00E	4.59	60.92	29.14	7.51	5576.55	151.24
25	45.00N	76.00E	4.57	60.19	29.50	5.52	5579.09	137.14

	LAT.	LONG.	MAG	MAJR(KM)	MINR(KM)	STRIKE	AREA	DEPTH
26	45.00N	77.00E	4.59	58.83	29.77	6.21	5503.11	152.39
27	45.00N	78.00E	4.58	59.88	29.16	5.78	5486.21	155.50
28	45.00N	79.00E	4.57	60.96	28.53	4.55	5463.73	158.46
29	45.00N	80.00E	4.56	60.07	27.92	4.13	5269.14	140.02
30	45.00N	81.00E	4.58	54.58	28.40	5.76	4869.50	139.80
31	46.00N	72.00E	4.68	52.98	29.21	14.07	4862.29	123.23
32	46.00N	73.00E	4.64	54.94	29.29	10.07	5055.60	136.75
33	46.00N	74.00E	4.60	59.57	30.20	8.98	5651.30	179.96
34	46.00N	75.00E	4.57	57.96	30.34	5.86	5524.57	156.73
35	46.00N	76.00E	4.56	58.78	30.20	5.79	5576.62	160.86
36	46.00N	77.00E	4.58	57.30	29.84	6.02	5372.05	158.32
37	46.00N	78.00E	4.58	57.39	28.84	4.26	5200.63	139.09
38	46.00N	79.00E	4.56	59.53	28.42	1.90	5314.50	143.27
39	46.00N	80.00E	4.55	58.55	29.25	1.91	5379.68	169.49
40	46.00N	81.00E	4.55	56.73	30.17	2.89	5377.02	175.47
41	47.00N	72.00E	4.64	51.35	30.45	12.90	4912.29	151.59
42	47.00N	73.00E	4.61	56.53	30.76	8.45	5462.81	178.09
43	47.00N	74.00E	4.58	55.95	30.19	3.21	5306.51	139.98
44	47.00N	75.00E	4.57	56.45	30.18	2.98	5352.32	142.23
45	47.00N	76.00E	4.56	55.41	30.10	3.35	5239.75	142.74
46	47.00N	77.00E	4.56	54.08	30.00	3.50	5097.29	144.29
47	47.00N	78.00E	4.54	54.07	30.39	3.53	5161.77	169.16
48	47.00N	79.00E	4.51	56.97	30.32	1.36	5426.99	178.51
49	47.00N	80.00E	4.52	57.17	30.91	1.06	5551.27	184.60
50	47.00N	81.00E	4.52	56.23	30.50	-1.31	5387.78	158.89

	LAT.	LONG.	MAG	MAJR(KM)	MINR(KM)	STRIKE	AREA	DEPTH
51	48.00N	72.00E	4.60	50.03	31.94	4.87	5020.10	149.23
52	48.00N	73.00E	4.57	50.15	31.55	3.87	4970.26	139.64
53	48.00N	74.00E	4.54	52.49	31.46	1.13	5188.65	144.61
54	48.00N	75.00E	4.54	53.70	32.06	1.30	5407.79	168.94
55	48.00N	76.00E	4.53	53.52	32.03	0.73	5385.95	171.97
56	48.00N	77.00E	4.52	52.26	32.42	1.57	5322.51	175.09
57	48.00N	78.00E	4.50	52.72	32.11	-1.03	5318.00	159.04
58	48.00N	79.00E	4.48	53.69	31.53	-1.47	5318.73	165.67
59	48.00N	80.00E	4.49	52.80	31.52	0.09	5228.79	167.56
60	48.00N	81.00E	4.50	54.19	31.21	-1.52	5314.05	170.48
61	49.00N	72.00E	4.55	49.95	36.01	-0.60	5649.98	162.93
62	49.00N	73.00E	4.52	50.71	35.10	-1.07	5591.96	167.36
63	49.00N	74.00E	4.49	53.35	34.46	-1.49	5776.70	178.46
64	49.00N	75.00E	4.48	52.13	33.71	-4.27	5520.61	158.49
65	49.00N	76.00E	4.49	52.19	33.46	-4.48	5486.06	162.13
66	49.00N	77.00E	4.50	51.68	33.61	-5.22	5456.27	162.57
67	49.00N	78.00E	4.49	51.58	33.00	-4.41	5347.53	167.42
68	49.00N	79.00E	4.49	50.16	31.95	-2.68	5034.57	171.39
69	49.00N	80.00E	4.48	50.69	31.99	-0.87	5094.97	177.36
70	49.00N	81.00E	4.48	54.10	32.10	0.30	5455.46	220.44
71	50.00N	72.00E	4.53	54.00	37.12	-13.63	6297.73	152.08
72	50.00N	73.00E	4.51	54.69	36.43	-11.31	6259.34	157.96
73	50.00N	74.00E	4.48	56.12	35.19	-10.26	6205.02	164.37
74	50.00N	75.00E	4.48	53.56	34.31	-7.96	5773.53	167.32
75	50.00N	76.00E	4.48	50.93	33.72	-6.60	5394.93	167.91

	LAT.	LONG.	MAG	MAJR(KM)	MINR(KM)	STRIKE	AREA	DEPTH
76	50.00N	77.00E	4.49	49.99	33.73	-5.78	5296.49	169.62
77	50.00N	78.00E	4.50	49.03	32.53	-6.29	5010.50	171.07
78	50.00N	79.00E	4.50	49.16	31.93	-5.96	4930.79	176.91
79	50.00N	80.00E	4.48	51.61	32.28	-2.12	5233.52	225.88
80	50.00N	81.00E	4.48	51.93	32.35	0.24	5277.24	233.94
81	51.00N	72.00E	4.51	54.19	38.18	-16.50	6499.43	161.91
82	51.00N	73.00E	4.51	54.77	36.79	-17.42	6329.96	163.19
83	51.00N	74.00E	4.50	56.47	35.36	-15.28	6272.67	170.08
84	51.00N	75.00E	4.48	56.06	34.45	-12.88	6067.53	174.02
85	51.00N	76.00E	4.48	53.15	33.91	-9.60	5662.15	177.33
86	51.00N	77.00E	4.51	48.08	33.44	-6.74	5051.45	174.09
87	51.00N	78.00E	4.52	45.70	32.08	-4.98	4606.13	175.73
88	51.00N	79.00E	4.50	51.23	32.01	-5.70	5151.23	230.33
89	51.00N	80.00E	4.50	51.04	31.97	-6.25	5126.57	234.57
90	51.00N	81.00E	4.50	49.40	32.04	-3.32	4972.32	240.09
91	52.00N	72.00E	4.51	53.73	38.72	-19.15	6536.28	170.25
92	52.00N	73.00E	4.51	54.46	37.20	-18.25	6365.45	173.97
93	52.00N	74.00E	4.50	56.59	35.81	-18.10	6366.76	178.06
94	52.00N	75.00E	4.49	58.13	34.59	-17.03	6316.73	182.04
95	52.00N	76.00E	4.50	53.06	33.93	-14.91	5654.88	181.35
96	52.00N	77.00E	4.52	47.46	33.93	-11.11	5058.88	181.92
97	52.00N	78.00E	4.50	50.10	33.25	-7.55	5233.13	238.81
98	52.00N	79.00E	4.48	50.24	32.46	-6.80	5122.27	247.85
99	52.00N	80.00E	4.50	47.75	32.20	-7.29	4830.03	245.75
100	52.00N	81.00E	4.52	46.75	32.23	-5.61	4733.10	248.29

	LAT.	LONG.	MAG	MAJR(KM)	MINR(KM)	STRIKE	AREA	DEPTH
101	33.00N	120.00W	4.60	114.98	44.25	12.09	15982.72	130.38
102	33.00N	119.00W	4.60	120.23	44.92	10.52	16967.50	127.73
103	33.00N	118.00W	4.59	132.78	44.53	10.72	18577.02	124.96
104	33.00N	117.00W	4.57	147.41	44.49	10.45	20601.83	124.73
105	33.00N	116.00W	4.56	155.68	45.59	9.23	22295.22	124.44
106	33.00N	115.00W	4.57	162.88	46.97	9.15	24035.42	126.22
107	33.00N	114.00W	4.56	152.61	46.32	9.01	22209.61	118.98
108	33.00N	113.00W	4.55	151.83	46.08	8.92	21978.97	119.26
109	33.00N	112.00W	4.54	144.91	52.65	8.74	23966.77	193.41
110	34.00N	120.00W	4.64	101.71	41.82	14.25	13360.92	124.02
111	34.00N	119.00W	4.62	108.94	41.95	12.27	14356.41	121.07
112	34.00N	118.00W	4.59	116.04	42.79	9.55	15598.77	119.49
113	34.00N	117.00W	4.59	121.73	43.46	9.07	16622.43	120.20
114	34.00N	116.00W	4.59	128.23	44.67	9.10	17994.02	120.51
115	34.00N	115.00W	4.58	133.83	45.14	8.79	18978.17	121.04
116	34.00N	114.00W	4.56	138.57	44.82	10.04	19511.56	116.55
117	34.00N	113.00W	4.55	127.93	45.18	10.17	18158.86	116.00
118	34.00N	112.00W	4.52	122.63	52.14	10.31	20087.78	194.88
119	35.00N	120.00W	4.66	94.02	39.90	15.20	11785.34	119.35
120	35.00N	119.00W	4.64	99.58	40.37	12.53	12629.63	118.25
121	35.00N	118.00W	4.62	102.91	40.90	10.97	13224.64	117.15
122	35.00N	117.00W	4.62	99.41	42.54	8.02	13285.61	120.56
123	35.00N	116.00W	4.61	105.25	43.13	8.33	14261.21	120.74
124	35.00N	115.00W	4.60	106.67	43.26	8.58	14496.25	118.64
125	35.00N	114.00W	4.59	107.75	43.47	10.41	14713.80	121.20

	LAT.	LONG.	MAG	MAJR(KM)	MINR(KM)	STRIKE	AREA	DEPTH
126	35.00N	113.00W	4.57	100.04	44.19	12.37	13887.56	120.88
127	35.00N	112.00W	4.54	96.35	51.84	14.20	15691.66	209.34
128	36.00N	120.00W	4.67	86.89	38.90	15.91	10618.90	117.54
129	36.00N	119.00W	4.67	92.59	38.98	15.16	11339.73	115.27
130	36.00N	118.00W	4.66	90.35	39.54	12.95	11224.05	115.96
131	36.00N	117.00W	4.65	90.82	40.69	10.92	11609.72	119.01
132	36.00N	116.00W	4.63	89.13	41.95	7.17	11746.83	123.83
133	36.00N	115.00W	4.63	89.28	42.48	8.41	11914.76	126.71
134	36.00N	114.00W	4.63	64.90	42.72	10.99	11394.23	126.42
135	36.00N	113.00W	4.61	70.32	41.15	22.05	9090.28	112.40
136	36.00N	112.00W	4.58	70.37	40.59	34.61	8973.58	161.51
137	37.00N	120.00W	4.68	83.74	38.06	17.09	10012.46	116.84
138	37.00N	119.00W	4.68	85.27	38.41	16.22	10290.61	116.46
139	37.00N	118.00W	4.68	83.75	38.91	14.88	10238.32	117.54
140	37.00N	117.00W	4.67	82.03	39.24	12.98	10113.01	119.90
141	37.00N	116.00W	4.66	75.86	40.74	9.32	9709.61	124.75
142	37.00N	115.00W	4.66	75.03	42.57	7.45	10034.29	131.39
143	37.00N	114.00W	4.65	62.19	41.81	19.20	8169.54	113.54
144	37.00N	113.00W	4.63	61.33	39.82	28.15	7671.08	110.79
145	37.00N	112.00W	4.61	59.75	37.55	46.47	7048.30	154.72
146	38.00N	120.00W	4.69	80.54	37.66	16.77	9527.60	120.02
147	38.00N	119.00W	4.70	76.79	37.96	16.62	9158.26	118.86
148	38.00N	118.00W	4.70	79.43	37.76	16.22	9423.25	118.63
149	38.CON	117.00W	4.70	75.85	38.31	14.35	9130.13	120.44
150	38.00N	116.00W	4.69	71.70	39.57	12.83	8913.77	124.66

	LAT.	LONG.	MAG	MAJR(KM)	MINR(KM)	STRIKE	AREA	DEPTH
151	38.00N	115.00W	4.68	58.24	40.67	19.99	7441.09	112.36
152	38.00N	114.00W	4.67	54.21	42.14	22.65	7177.13	112.79
153	38.00N	113.00W	4.65	52.98	39.75	34.96	6616.11	110.42
154	38.00N	112.00W	4.63	50.89	37.01	47.78	5917.91	105.81
155	39.00N	120.00W	4.66	75.41	37.04	17.97	8775.48	122.83
156	39.00N	119.00W	4.68	75.83	37.31	16.12	8888.07	122.53
157	39.00N	118.00W	4.70	74.80	37.30	15.83	8764.26	122.14
158	39.00N	117.00W	4.71	62.77	37.31	20.10	7358.30	106.57
159	39.00N	116.00W	4.71	59.20	38.18	21.94	7099.77	107.54
160	39.00N	115.00W	4.70	53.04	39.87	25.21	6644.18	109.76
161	39.00N	114.00W	4.69	50.63	39.91	31.80	6349.18	109.43
162	39.00N	113.00W	4.67	48.11	40.10	40.65	6060.32	107.53
163	39.00N	112.00W	4.66	47.59	37.46	54.10	5600.53	105.87
164	40.00N	120.00W	4.63	71.96	36.31	19.02	8208.03	125.40
165	40.00N	119.00W	4.65	71.24	36.75	17.06	8224.36	125.21
166	40.00N	118.00W	4.68	64.12	37.20	18.76	7493.52	110.86
167	40.00N	117.00W	4.69	61.77	37.66	20.99	7308.79	108.85
168	40.00N	116.00W	4.71	55.98	38.66	23.83	6798.73	108.10
169	40.00N	115.00W	4.71	52.06	38.71	27.40	6331.22	106.88
170	40.00N	114.00W	4.71	48.07	39.27	33.52	5930.65	106.65
171	40.00N	113.00W	4.69	46.06	38.78	46.16	5611.85	105.59
172	40.0CN	112.00W	4.68	44.42	38.23	62.40	5335.39	102.78

STATION IMPORTANCE SETS
ELLIPSE FOLLOWED BY DEPTH

IMPORTANCE SET 1

STATN	P-WV MIN.	P-WV AVE.	P-WV MAX.	PG-W MIN.	PG-W AVE.	PG-W MAX.	LG-W MIN.	LG-W AVE.	LG-W MAX.	S-WV MIN.	S-WV AVE.	S-WV MAX.
1	1.0000	1.0000	1.0000	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0000	1.0000	1.0000	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
2	1.0715	1.1765	1.3421	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0188	1.0626	1.1200	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
3	1.0005	1.0011	1.0023	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0001	1.0003	1.0010	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
4	1.0014	1.1125	1.1785	1.0098	1.0584	1.1167	1.0001	1.0005	1.0016	100.0000	0.	0.
	1.0009	1.0280	1.0537	1.0316	1.2171	1.4187	1.0000	1.0002	1.0007	100.0000	0.	0.
5	1.0008	1.0107	1.0625	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0008	1.0099	1.0607	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
6	1.0703	1.1366	1.2139	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0000	1.0038	1.0111	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
7	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
8	1.0001	1.0013	1.0051	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0001	1.0013	1.0052	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
9	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
10	1.0000	1.0160	1.1437	1.0210	1.0578	1.1220	1.0003	1.0009	1.0021	100.0000	0.	0.
	1.0000	1.0021	1.0139	1.0667	1.2826	1.5168	1.0000	1.0001	1.0003	100.0000	0.	0.
11	1.0047	1.0383	1.1255	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0004	1.0069	1.0252	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
12	1.0051	1.0184	1.0257	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0021	1.0049	1.0084	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
13	1.0025	1.0080	1.0210	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0006	1.0018	1.0042	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
14	1.0027	1.0056	1.0136	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0003	1.0012	1.0043	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
15	1.0015	1.0043	1.0101	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0002	1.0010	1.0023	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
16	1.0020	1.0039	1.0069	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0002	1.0009	1.0021	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
17	1.0010	1.0043	1.0158	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0001	1.0009	1.0041	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
18	1.0014	1.0053	1.0312	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0000	1.0003	1.0024	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
19	1.0013	1.0037	1.0098	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0000	1.0000	1.0004	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
20	1.0544	1.1518	1.2264	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0061	1.0286	1.0564	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
21	1.1444	1.4309	1.7931	1.0324	1.0480	1.0605	1.0001	1.0001	1.0002	100.0000	0.	0.
	1.0648	1.2318	1.5385	1.0620	1.0882	1.1452	1.0000	1.0001	1.0001	100.0000	0.	0.
22	1.3147	1.5022	1.7356	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.
	1.0014	1.0377	1.1007	100.0000	0.	0.	100.0000	0.	0.	100.0000	0.	0.

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Appendix

DESCRIPTION OF THE LOCATE MODULE*

GENERAL DESCRIPTION

The module LOCATE predicts the error a seismic network would commit in locating an event of a given magnitude and true location. The expected location error is expressed in the form of confidence regions for the epicenter and focal depth estimates that would be derived from the seismic data the network is predicted to observe. The possible data consist of the arrival times of one or more seismic phases at each station and back azimuth measurements obtained from Lg.

The location confidence regions are inferred from the following principal inputs:

- The network station locations with respect to the true epicenter, and the true focal depth of the event.
- The probability that each seismic phase is observed at each station (the p_{ijk}).
- The standard error of the datum obtained from each detected phase (the σ_{ijk} or $\sigma_{\beta i}$).
- Travel time versus distance tables contained in the wave files which describe the theoretical dependence of the arrival-time data on the event hypocenter.

The focal depth of the event is restricted to be either 0, 15, or 100 km, representing an explosion, shallow earthquake, or deep earthquake, respectively. The magnitude of the event is not input explicitly, but is reflected in the observation probabilities.

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*Systems, Science and Software developed the LOCATE module and provided this general description of its operation.

These inputs determine the distribution of location estimates that would be derived from randomly selected sets of network data; namely, the probability density function $f(\hat{\underline{h}})$. The vector $\hat{\underline{h}}$ denotes an estimate of $\underline{h}$, the four-element vector of true location parameters:

$$\underline{h} = (\theta, \phi, z, t)^T ,$$

where θ and ϕ are the epicenter coordinates, z is the focal depth, and t is the origin time. It is assumed that $\hat{\underline{h}}$ is the "best" estimate that can be derived from any sample of data; e.g., the minimum-variance unbiased estimate. The distribution of $\hat{\underline{h}}$ can be shown more completely as $f(\hat{\underline{h}}|\underline{h})$, since it depends on the true location $\underline{h}$. However, we will denote it simply as $f(\hat{\underline{h}})$ for the sake of brevity.

From the multivariate distribution $f(\hat{\underline{h}})$ one can define a four-dimensional confidence region for any given confidence level P_c. The location estimate derived from a particular network data set would have a P_c probability of falling within this region.

For nuclear monitoring applications it is useful to know the separate confidence regions of the epicenter estimate $(\hat{\theta}, \hat{\phi})$ and focal depth estimate $\hat{z}$. These are obtained from the marginal distributions $f(\hat{\theta}, \hat{\phi})$ and $f(\hat{z})$. The focal depth confidence interval, $z_1 \le \hat{z} \le z_2$, is defined by

$$\int_{z_1}^{z_2} d\hat{z}\, f(\hat{z}) = P_c ,$$

$$f(z_1) = f(z_2) .$$

The two-dimensional epicenter confidence region E and its boundary ∂E are defined by

$$\iint_{E} d\hat{\theta}\, d\hat{\phi}\, f(\hat{\theta}, \hat{\phi}) = P_c$$

$$f(\hat{\theta}, \hat{\phi}) = \text{constant on } \partial E \ .$$

With appropriate assumptions and approximations, $f(\hat{\underline{h}})$ is a normal distribution, implying that $f(\hat{\theta}, \hat{\phi})$ and $f(\hat{z})$ are normal. As a result, the epicenter confidence region is bounded by an ellipse.

The principal outputs of LOCATE for epicenter j are A_j, the area of the epicenter confidence ellipse, and d_j, the length of the focal depth confidence interval. In addition, LOCATE returns the lengths and orientations of the principal axes of the epicenter confidence ellipse.

LOCATE also calculates the relative importances of the individual data (i.e., station i observing wave k) to the overall network location capability. The importance of a datum with respect to a location parameter measures how much the confidence region for that parameter would increase if the datum were removed from the data set while retaining all the other data:

$$\text{Importance} = \frac{\text{Confidence region without datum}}{\text{Confidence region with datum}} \ .$$

Two importances are defined for each epicenter j: $\gamma_{ik}^{A_j}$, the importance of station i and wave k with respect to the epicenter estimate, and $\gamma_{ik}^{d_j}$, the importance with respect to the depth estimate. They measure the dependence of A_j and d_j, respectively, on the datum.

The LOCATE module is called in a loop in which the true event epicenter is varied from call to call while the true focal depth and network configuration are held constant. (The detection probabilities and data standard errors depend on the event-station distances, so they vary with the epicenter.) An initialization call to LOCATE precedes the loop, and a finalization call follows it.

Each call to LOCATE within the loop returns the epicenter and focal depth confidence regions for the event having the current epicenter. The data importances, however, are obtained for sets of epicenters Γ_m, m = 1, ..., M, rather than for each individual epicenter. The importances obtained for the events in a given set Γ_m are reduced to six values for each station/wave pair: the minimum, maximum, and average values of $\gamma_{ik}^{A_j}$ and $\gamma_{ik}^{d_j}$ over the set. The purpose of grouping the importances in this way is to find the importance of a given station/wave combination over user-specified geographical regions.

DATA MODELED

LOCATE models data from five seismic phases: P, Pg, Lg, S, and pP. The data from all but the Lg phase are assumed to be arrival times; Lg is assumed to provide an estimate of the event-station back azimuth. The P wave at a given station may be either Pn, mantle-refracted P, or PKP, depending on which is the first arrival for the event-station distance. Pg is considered separately since in practice it can be observed as either a first or later arrival. The S wave is also a composite phase (Sn, S, or SKS), but it can be used only from paths for which the P to S velocity ratio (v_P/v_S) is assumed to be calibrated (i.e., the S-P technique).

LOCATE's multiphase capability makes it possible to simulate a variety of seismic location techniques currently in use: a conventional location with P times, the Lg back azimuth technique, master-event calibration of P times, origin-time constraint with S-P times from v_P/v_S calibrated paths, and focal depth determination with pP-P times. The last three techniques are described by Evernden [1969]. LOCATE models these techniques automatically when the appropriate arrival times (P, S, or pP) belong to the data set and when some modifications are made to the arrival-time standard errors as discussed in the "ATSD" subsection of Sec. IV.

LOCATE calculates the confidence regions that would result from a simultaneous estimation of all four location parameters (epicenter

coordinates, focal depth, and origin time), using all the data from the various phases and network stations. The simultaneous estimation approach makes most efficient use of the data and produces the minimum-variance estimate of each location parameter. However, this approach is not always taken in practice. For example, the S-P and pP-P techniques are often applied separately to constrain origin time and focal depth, and then the inferred constraints are applied in an epicenter determination from P times. This and other variations on multiphase event location approximate the simultaneous estimation approach, but they are not explicitly modeled by LOCATE.

NETWORTH [Wirth, 1977], on the other hand, does effectively model the step-wise, as opposed to simultaneous, approach to epicenter estimation. NETWORTH models an epicenter determination from P times, given that the focal depth is known from other data (e.g., constrained by S-P and pP-P). In mathematical terms, NETWORTH calculates the epicenter confidence region from $f(\hat{\theta}, \hat{\phi} | \hat{z} = z)$, whereas LOCATE calculates it from $f(\hat{\theta}, \hat{\phi})$ which is marginal, rather than conditional, with respect to $\hat{z}$.

STATISTICAL FORMULATION OF EVENT LOCATION

To properly describe the location capability of a network, the confidence regions determined by LOCATE must reflect two sources of uncertainty in the expected network data set: data errors and undetected phases. Finding confidence regions that account for the data errors is a straightforward problem in linear estimation. Accounting for undetected phases is a more difficult problem.

A data error is any deviation of an observed datum from the value that would be predicted theoretically if the event location were known. Thus, the observed datum from the *kth* seismic phase at the *ith* station is related to the true event location $\underline{h}$ by

$$g_{ik} = G_{ik}(\underline{h}) + e_{ik} ,$$

where g_{ik} is the datum, G_{ik} is the "data function" expressing the theoretical dependence of the datum on $\underline{h}$, and e_{ik} is the data error.

Data errors can result from observational errors, such as the reading error in an arrival-time measurement, or modeling errors, such as errors in the travel-time tables used for predicting theoretical arrival times.

With some simple assumptions about e_{ik} and G_{ik}, the location confidence regions implied by a given set of detected data can be easily derived. The error in each datum is assumed to be a normally distributed zero-mean random variable with known variance:

$$E[e_{ik}] = 0$$

$$\mathrm{Var}[e_{ik}] = \sigma_{ik}^2 ,$$

where σ_{ik} is the standard deviation of the data error or, more simply, the standard error. Then if each G_{ik} is approximated by a linear function, the minimum-variance unbiased location estimate $\hat{\underline{h}}$ is a linear function of the observed data. Expressions for its distribution $f(\hat{\underline{h}})$ and its confidence regions are rather simple.

Since undetected phases contribute no data to the network data set, the subset of data that would be available for deriving a location estimate is, like the data errors, a random element that must be accounted for in the location confidence regions. The probability of detection p_{ik} (suppressing the constant index j) assigned to each phase at each station is essentially the probability that the (i, k)*th* datum will be part of the network data set. Equivalently, the (i, k)*th* datum has a finite standard error with probability p_{ik} and an infinite standard error with probability $(1 - p_{ik})$.

The best way to account for the p_{ik} is not obvious. One approach is to average the confidence regions computed for pseudo-randomly selected subsets of data, selected according to the detection probabilities. Another approach is to compute the confidence regions for the most probable data subset containing a specified number of data. These approaches are implemented in NETWORTH. While they do account for the effect of undetected phases on location performance, they

define the expected average performance of a network in a rather subjective way. Further, the first approach may take a substantial amount of computation.

The most meaningful approach to the problem of undetected phases, and the approach taken by LOCATE, is to define the location confidence regions from the probability distribution of $\underline{\hat{h}}$ that treats both the data subset and data errors as random variables. That is, the distribution of location estimates that would result from random sampling of both the subset of detected data and the data values themselves. This is accomplished by treating the standard errors as random variables having the discrete distribution

$$\text{Prob}\ [\sigma_{ik} = \sigma^{d}_{ik}] = p_{ik}\ ,$$

$$\text{Prob}\ [\sigma_{ik} = \infty] = 1 - p_{ik}\ ,$$

where σ^{d}_{ik} is the standard error of the datum obtained from a detected phase. The distribution described earlier--namely, that of the minimum-variance estimate obtained from a given data subset--is actually the *conditional* distribution $f(\underline{\hat{h}}|\sigma_{ik})$. The distribution that accounts for undetected phases is *marginal* with respect to the σ_{ik}. We now show the latter as $f(\underline{\hat{h}})$.

The exact marginal distribution of $\underline{\hat{h}}$ is quite difficult and costly to compute. Further, it is not a normal distribution, even when the errors are normal, since the standard errors are not normally distributed. Therefore, obtaining the nonellipsoidal confidence regions from $f(\underline{\hat{h}})$ would be quite involved even if the distribution were known.

Fortunately, an approximation to the marginal distribution of $\underline{\hat{h}}$ can be evaluated as easily as its conditional distribution. The approximation in fact is to evaluate the conditional distribution with weighted standard errors:

$$f(\hat{\underline{h}}) \approx f(\hat{\underline{h}}|\sigma_{ik} = \tilde{\sigma}_{ik}) ,$$

where

$$\tilde{\sigma}_{ik} = \sigma^{d}_{ik}/\sqrt{p_{ik}} .$$

Thus, the effect of undetected phases can be approximated by assuming every phase is detected and produces a datum whose error is increased by a factor depending on the probability of detection.

The approximate $f(\hat{\underline{h}})$ is a normal distribution, so the approximate confidence region of $\underline{h}$ is ellipsoidal. The accuracy of the approximation, it turns out, is indicated by the size of the data importances. The approximation is accurate when the individual data are not very important ($\gamma^{A_j}_{ik}$ and $\gamma^{d_j}_{ik} \gtrsim 1$).

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